Environmental management of deep-sea chemosynthetic ecosystems: justification of and considerations for a spatially based approach.

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Environmental Management of Deep-Sea Chemosynthetic Ecosystems: Justification of and Considerations for a Spatially-Based Approach

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EXECUTIVE SUMMARY

Thirty-one experts in ocean governance, industry and marine scientific research from 14 countries convened from 31 May to 4 June 2010 at the Centre de Recherche et d'Enseignement sur les Systèmes Côtiers (CRESCO) in Dinard, France, in order to:

- Formulate general guidelines for the conservation of vent and seep ecosystems at regional and global scales.
- Establish a research agenda aimed at improving existing plans for the spatial management of vent and seep ecosystems.

Deep-sea vent and seep ecosystems were first discovered in the late 1970s and mid-1980s, respectively, and are considered among the greatest scientific discoveries of the 20th century. The new insights gained from the study of these ecosystems include:

- A fundamental understanding of Earth processes (for example, convective cooling of the ocean crust, sub-crustal processes contributing to the chemical composition of seawater, and the submarine origin of major land-based ore bodies).
- An appreciation that life can exist in the absence of sunlight and oxygen, sometimes at very high temperatures (up to 121°C).
- The discovery of novel bacterial-invertebrate symbioses based on chemosynthetic processes and a host of biochemical, physiological, anatomical and behavioural adaptations for life in chemosynthetic systems.
- A definition of the lower branches of the 'Tree of Life.'
- The recognition that chemosynthetic systems may have played a role in the origin of life on Earth and that chemical energy (rather than sunlight) may support life on other planets.

This report reviews the basic characteristics of vents and seeps, considers the relative impact of various human activities on vents and seeps, and provides an overview of current and emerging concerns for the management of these ecosystems, including conservation needs and international mandates. Bottom fishing in seep areas and emergent seafloor massive sulphide extraction at vents need to be addressed as a matter of priority in the context of the spatial management of vent and seep habitats. Extractable resources (for example, mineral, oil, gas, gas hydrate) at vents and seeps are fossil in nature and are therefore non-renewable. Even though mineral deposits can form quickly at vents, commercial ore deposits only accumulate over thousands of years. Oil, gas and gas hydrates at seeps accumulate over millennia.

A number of policy instruments relevant to the conservation of biodiversity in the marine environment are now integral parts of international, domestic and customary law. Deep-sea chemosynthetic environments span multiple jurisdictional boundaries, and only a handful of countries have to date established protected chemosynthethic environments in their national waters.

This document presents the first design principles for the comprehensive management of chemosynthetic environments in the global ocean and serves to introduce chemosynthetic ecosystems into the discourse of systematic marine spatial planning.

DINARD GUIDELINES FOR CHEMOSYNTHETIC ECOSYSTEM RESERVES

The Dinard Guidelines call for networks of Chemosynthetic ecosystem reserves (CERs) to enable chemosynthetic-based area management of the seabed, to achieve the conservation goal of protecting the natural diversity, ecosystem structure, function and resilience of chemosynthetic ecosystems, while enabling rational use. Chemosynthetic Ecosystem Reserves may be managed with various levels of protection, ranging from multiple uses, to restricted use, to fully protected.

1) The Dinard Guidelines for the spatial design of CERs at vents and seeps:

- Identify chemosynthetic sites that meet the Convention on Biodiversity criteria for Ecologically and Biologically Significant Areas (EBSAs) or that are otherwise of particular scientific, historical or cultural importance to merit priority consideration for protection.
- Define the regional framework for protection of biodiversity. Natural management units (biogeographic provinces and bioregions) form the ecological framework within which CERs should be established for the protection of chemosynthetic ecosystems.
- Establish the expected distribution patterns of chemosynthetic habitats to provide a spatial framework for capturing representativity.
- Establish CERs and design replicated networks of CERs within bioregions, using guidelines for size and spacing that ensure connectivity and that take into account the pattern of distribution of chemosynthetic habitats, which may vary from semi-continuous to widely dispersed.
- Define human uses and the levels of protection for each CER to achieve the conservation goal.

2) The Dinard Guidelines for management of CERs:

- Use a two-level approach for identifying CERs: a) select CER sites of extraordinary value; b) establish networks of CERs. Combined, these spatial management designs will contribute to the conservation goal.
- Use adaptive management strategies to compensate for uncertainty and new knowledge.
- Establish CERs in a manner that is consultative and transparent.
- Governance of CERs should occur within existing governance regimes wherever possible.

- Where CERs include activities with the potential to cause significant adverse environmental effects, Environmental Impact Assessments (EIAs) that follow best practices should be required for these activities.
- Establish monitoring strategies to assess the spatial and temporal impacts of cumulative activities relative to the conservation goal and objectives.
- Use a set of prescriptive criteria, established before multi-use activities begin, to trigger closer monitoring or cessation of activities that jeopardize the conservation goal within a bioregion.

Through three decades of research, scientists have learned much about the basic properties of vent and seep ecosystems, but from a management perspective, there are critical knowledge gaps primarily related to the degree of connectivity (e.g. larval dispersal, settlement, recruitment, gene flow, etc.) among sites, the resilience of vent and seep ecosystems, and the effectiveness of mitigation and restoration strategies. At present, for example, there is very little understanding of source-sink dynamics or what an effective network of protected areas might look like, except that the optimal network size and spacing will be different for vents and seeps and within bioregions of vents and seeps. These unknowns should not prevent the emplacement of management strategies but they do argue for a precautionary and adaptive approach to management.

CHAPTER ONE

Background

1. Background

Deep-sea vent and seep ecosystems were first discovered in the late 1970s and mid-1980s, respectively, and are considered to be among the greatest scientific discoveries of the 20th century. An impressive number of insights have been gained following the study of these ecosystems, ranging from fundamental knowledge of Earth processes (for example, convective cooling of the ocean crust, sub-crustal processes contributing to the chemical composition of seawater, and the submarine origin of major land-based ore bodies) to an understanding of the various ways life can exist in the absence of sunlight and oxygen, sometimes at very high temperatures (up to 121°C), to defining the lowest branches of the 'Tree of Life' and possibly the origin of life itself on Earth and on other planets. Hundreds of previously undescribed species have been discovered. Many are apparently endemic to the vent or seep environment, and may belong to higher-level taxa (genera and families) not previously known to science. Extractable resources at vents (mineral) and seeps (oil, gas, gas hydrate) are fossil in nature and non-renewable. While mineral deposits can form quickly at vents, commercial ore deposits, as well as oil, gas and gas hydrates at seeps accumulate over millennia.

1.1 Attributes of vents and seeps

Both vent and seep ecosystems are fueled primarily by microbial primary production through a process known as chemosynthesis. Instead of using energy from sunlight to fix inorganic carbon into organic carbon (photosynthesis), microbes in vent and seep ecosystems use chemical energy from the oxidation of reduced chemical compounds. Microbial cells form the basis of the vent and seep food webs. While these microbial cells may be free-living and grazed upon directly by animals, most of the standing biomass at vents and seeps is typically found in invertebrates that host chemosynthetic microorganisms as symbionts. There are exceptions, such as the dense ampharetid polychaete beds to be found in New Zealand seeps that derive their nutrition through free-living autotrophic microorganisms. Different invertebrate groups in different environmental settings accommodate this chemosynthetic symbiosis in different morphological, physiological and biochemical ways; the consequence is that we can expect to continue to find novel adaptations to vent and seep environments as we discover previously unknown sites and species, expanding our understanding of the fundamental diversity of life.

Whereas there is typically little overlap at the species level between vent and seep habitats, there is often a remarkable, shared evolutionary history among the conspicuous taxa found there (for example, bathymodiolin mussels, vesicomyid clams, vestimentiferan tubeworms, alvinocarid shrimp) and shared characteristics of community structure, for example, relatively low species richness in the order of 100-200 species or fewer within sites; numerical dominance by a few species; biomass dominance by symbiont-hosting invertebrates; a large number of rare species (represented by <5 individuals in quantitative samples of thousands or more individuals of other taxa). More importantly, perhaps, from the perspective of marine management, including conservation goals, is the natural variety of vent and seep sites (for example, in terms of faunal composition, geological setting and hydrographic conditions) at regional and often even local scale. The full scope of diversity of habitats and adaptations to life in deep-sea chemosynthetic ecosystems is unknown. Our knowledge will expand substantially as our exploration and understanding of the deep sea continues to develop.

Adults of most biomass-dominant vent- and seep-endemic species are relatively sessile or attached; the persistence of vent and seep species and maintenance of local populations is accomplished primarily through dispersive planktonic larval stages. There are thus critical links between the spacing of suitable habitats, regional ocean circulation patterns, the duration of larval life, and larval behaviors that allow larvae to locate at island-like vent and seep habitats where they may survive and reproduce.

The scaling characteristics of vents and seeps are roughly similar (Table 1); and resemble small islands in the vastness of the deep sea, where each vent or seep site is separated from its closest neighbour by relatively large expanses of non-chemosynthetic seabed habitats. Within this spatial context, each vent or seep site comprises a mosaic of habitat patches (microbial mats, clam beds, mussel beds, etc.). In addition, chemosynthetic faunas may be differentiated geographically, with depth, and by habitat type (for example, vent vs. seep, clam bed vs. mussel bed).

Table 1. Scaling characteristics in chemosynthetic ecosystems

Level	Category	Description	Typical maximum dimension
α	Within patch diversity	Microbial mat, clam bed, tubeworm clump, mussel bed, inactive substrata, etc.	1 m to 100 m
β	Among patches, within site	A collection of heterogeneous patches in a seep or vent system that is geographically constrained and dynamically closely interlinked; there may be more than one site in a seep or vent system	10 m to 10 km
γ	Intersite	Distance between sites	1 km to 100 km
δ	Bioregion	Sites with similar community composition and with faunal overlap at the genetic level	500 km to 2,500 km*
ε	Biogeographic province	One or more bioregions with faunal overlap at the species level	500 km to 5,000 km*
z	Depth zone	A depth range containing a single bioregion	100 m in Oxygen Minimum Zones; between 500 and 1,000 m elsewhere*

**not well known, especially for seeps*

NB. This report applies a consistent scaling terminology agreed upon by workshop participants; elsewhere, a patch may be referred to as a 'habitat'; a system of sites is often referred to as a 'vent field' by vent scientists (for example, Lucky Strike is a vent field on the Mid-Atlantic Ridge, made up of vent sites [for example, Eiffel Tower, Statue of Liberty], within which there may be a variety of habitat patches).

While similarities between vent and seep faunas allow us to develop basic design principles for area-based management of human activities that apply to both systems, it is also important to capture key contrasts. Geological settings, distribution, biogeochemistry and the dynamics of vent and seep ecosystems often have different characteristics, ranging from the source of reduced compounds available for microbial transformation into energy through chemical oxidation, to the nature of the substratum, to durations of habitats and life spans of dominant taxa (Table 2).

Point locations and patchy spatial distribution of vent and seep ecosystems and their biogeographic patterns predispose them to a spatially based approach to management, as is the case in many shallower coastal marine ecosystems. The occurrence and distribution of vents and seeps can be predicted by geological and geochemical features, allowing for management in the absence of complete knowledge of vent and seep distribution. Spatially-based management approaches can: complement and provide guidance to single-sector management to reduce conflict across sectors; balance development and conservation interests; increase institutional effectiveness and efficiency; and address the cumulative effects of multiple human uses in the same marine space (Ehler and Douvere, 2009). In this report, we present principles for the design of spatial approaches for protecting chemosynthetic ecosystems and managing human uses of vents and seeps.

Table 2. Some contrasting characteristics of deep-sea vent and seep ecosystems

Characteristic	Vent	Seep
Source of reduced compounds	Water-rock interaction at high temperatures (~120°C) and pressure (100s of atm) or at low temperature under serpentinization	Hydrocarbon generation due to microbial and thermogenic degradation of organic material; sulphate reduction (= sulphide production) coupled to anaerobic methane oxidation of methane or other hydrocarbon degradation
Location	Spreading centers at mid-ocean ridges and in back-arc and fore-arc basins; active hot spots (intraplate seamounts)	Active and passive continental margins from coastal areas to deep-ocean trenches
Related structures	Axial graben, off-axis seamounts (East Pacific Rise), rift valley and slopes, oceanic core complexes (Mid-Atlantic Ridge), calderas (arc systems)	Brine pools, pock marks, mud volcanoes, salt diapirs, subducting seamounts
Hosted rocks	Crustal (basalt) or mantle (ultramafic) rocks, (rarely sediment)	Sediment; carbonate, sandstone or other permeable rock strata
Associated formations	High-temperature massive sulphides, low –temperature hydrothermal mineralization (sulphide, carbonate, opal, hydrothermal (Fe-Mn) crusts, metalliferous sediments; carbonate chimneys in serpentinite systems (i.e. Lost City)	Authigenic carbonates forming platforms, mounds, pinnacles; methane hydrates

Table 2. Ctnd...

Characteristic	Vent	Seep
Physical effects on the water column	Buoyant plumes of diluted hydrothermal effluents rise to levels of neutral buoyancy and then spread along isopycnal surfaces, transporting the effluents as well as additional material (chemicals, particulates, larvae) entrained during plume rise	Gas-bubble rise ('flares') with or without bubble water plume formation (may be episodic); sufficiently vigorous bubble flares cause strong upwelling flow that could vertically transport entrained materials
Biogeographic provinces	Incompletely mapped, but this has been a focus of exploration for some time and considerable progress has been made; six or more are recognized	Largely unknown, but could be developed further for some assemblages
Physico-chemical challenges to animal physiology	Low pH (except Lost City, with high pH), sulphide toxicity, heavy metal toxicity, extreme temperatures (beyond the limits for life) and steep temperature gradients (2°C to 350°C and more, sometimes across millimeter distances), radiation, low oxygen	Sulphide toxicity, hydrocarbon toxicity, oxygen depleted sediments, margins of oxygen minimum zones, low pH in sediments
Depth variation and biogeography	Depth may be important, but extensive biogeographic provinces along ridges tend to be at the same depth (exceptions include seamounts)	Depth is an important variable in differentiation of fauna within most regions. An example is found in the Gulf of Mexico, where there is greater variation in faunal composition along depth gradients than along comparable or greater horizontal distances along broad isobaths
Biodiversity	Proportion of species apparently endemic to vents is relatively high (~85%)	Proportion of species apparently endemic to seeps is relatively low (~50%) compared to vents (related to presence of infaunal species in sediments)
Connectivity to background benthic communities	Population dynamics and species interactions (e.g. competition, predation) of most vent species are relatively isolated from those of adjacent seabed communities	Population dynamics and species interactions of many non-symbiont-bearing seep species are relatively more connected to those of adjacent seabed communities than vents, including predation by non-seep endemics ("vagrants")
Life span of biomass dominant taxa, active sites	Generally assumed to be relatively short (years for shrimp, up to a decade or more for large bivalves such as *Calyptogena magnifica*)	Variable, with some taxa known to live for centuries (e.g. seep tubeworms in the Gulf of Mexico) and others known to colonize and reproduce within a year (limpets)
Life span of biomass dominant taxa, inactive sites	May be long-lived, as in the case of corals; poorly studied	May be long-lived, as in the case of corals; poorly studied

Table 2. Ctnd...

Characteristic	Vent	Seep
Duration of activity	Variable: less than decades where volcanic activity is frequent (e.g. East Pacific Rise); longer (to thousands of years) at tectonically dominated sites (e.g. TAG and other vent sites on the Mid-Atlantic Ridge); also depends on scale – there is within-site variability (months to years) driven by processes such as volcanic eruptions, earthquakes, etc.	Generally very long-lived (centuries and longer, but variable within site and not well known for all types of systems)
Likely recovery time following a major disturbance	Relatively fast recovery to pre-disturbance levels (within a decade) at active sites, at least for dominant taxa on the East Pacific Rise and Juan de Fuca Ridge; recovery times at Mid-Atlantic Ridge vents is unknown; decades or longer (if at all) for recovery at inactive sites	Not known, but presumed to be relatively slow recovery to pre-disturbance levels (decades or more) where taxa are long-lived, such as in the case of 100(+)-year-old vestimentiferan tubeworms at seeps; microbial activity remains for an unknown period in carbonates after seepage subsides
Fate after active phase	Inactive sites are colonized by non-vent taxa, including long-lived deep-sea corals; the extent of microbial primary production or other microbial processes of interest after fluid flux ceases is not well understood	Where authigenic carbonates are produced, these may become substrata for deep-water coral reefs and other non-seep, continental slope taxa
Relative abundance of sites	For mid-ocean ridge vent systems, from one site every 1-10 km to one site every 100 km, correlated with melt supply	Up to thousands of sites along certain regions of sedimented continental margins (e.g. Gulf of Mexico); in other areas the frequency of seep sites is not well known
Knowledge of distribution of active and inactive sites	Active sites along certain segments of ridge axes are mapped, but exploration is very incomplete; prospecting for inactive sites is more challenging than for active sites because there is no water column signal (though electromagnetic anomalies and geochemistry and mineralogy of adjacent sediments may prove to be useful prospecting tools)	Very localized and not well known for many continental margins; inactive sites/ old carbonates have mainly been studied near shore (e.g. New Zealand, Bulgaria) and not offshore; not well known for most continental margins; mapping of bottom simulating reflectors (BSR) and other geophysical tools may allow extensive prediction of seep locations
Legal jurisdictions	Mid-ocean ridge settings are mostly (but not exclusively) in areas beyond national jurisdiction; vent systems in arc settings are typically in Exclusive Economic Zones (EEZ), including Territorial Seas	Generally within EEZs and under jurisdiction of coastal states, but there may be examples that are in the Area (e.g. seeps associated with subduction zones?)
Present status	More or less undisturbed; scientific research is currently the greatest use of these systems, including sampling and establishment of long-term observatories with repeated disturbance	Shallower seeps (<1,000m) likely to be extensively disturbed by trawling (e.g., Hikurangi Margin, New Zealand), long-lining, pipelines/rigs/cables and other energy extraction activities; deep seeps used for scientific research

1.2 Human values and activities associated with vents and seeps

Do seeps or vents have ecological values that provide important ecosystem services to humans? Vents and seeps have non-use values that are cognitive in nature and arise from simply knowing that vents, seeps, and the animals that live in them, exist now (existence value) and will exist into the future for subsequent generations (bequest value). Diversity associated with vents and seeps contains evolutionary potential in the form of genes, metabolic pathways, novel organs and physiological tolerances. This potential is critical for the long-term persistence of life on Earth.

There are at least eight non-ecological services (i.e. provisioning or cultural activities that may have economic or other values) of vent and seep ecosystems that can presently be identified:

Existing activities

Fisheries: Seep habitats (active and inactive) may serve as primary habitats, refuges or attractors for certain commercially fished species. A number of commercially important fishes appear attracted to structure (and possibly food) created at seeps, including the Patagonian toothfish in the south-east Pacific, rockfishes and sablefish (black cod) in the north-east Pacific, and orange roughy in the south-west Pacific.

Oil, gas extraction: Seeps often overlie significant reserves of oil and gas that are extracted using deep-water technologies.

Scientific research: From the moment of their discovery, vents and seeps have served as important resources for scientists in their effort to understand Earth and Ocean dynamics, the diversity of life on Earth, evolution and adaptation of life under extreme conditions, and the origin of life on Earth (and elsewhere).

Education: Vents and seeps continue to serve as focal points for documentary films and other educational and outreach materials relating to, for example, dynamic Earth processes, the diversity of life on Earth, exploration and discovery.

Emergent activities

Mineral extraction: Mineral precipitation at deep-sea vents creates seafloor massive sulphide (SMS) deposits that may be rich in copper, gold, zinc and other metals that can be of sufficient size and quality to be of commercial value under certain economic and political regimes.

Gas hydrate extraction: Extensive methane hydrate deposits associated with and underlying some seeps are also targeted by emergent extractive technologies. Gas hydrates represent the largest potential energy reservoir on Earth.

Biotechnology: Microbes and animals adapted to deep-sea seep and vent environments are model systems in which to prospect for genetic resources and chemical compounds of value as therapeutic agents, innovative enzymes for commercial processes, and other products of interest to the biotechnology industry.

Tourism: There is an emerging but very limited market for extreme tourism, occupied by deep-ocean expeditions, which has taken more than 40 individuals to hydrothermal vents (Leary, 2007).

Each of the human activities associated with non-ecological services of vents and seeps may have different levels of impact on vent and seep ecosystems. There are, in addition, a number of anthropogenic pressures arising from indirect commercial activities, such as shipping, cable laying and waste disposal, which may impact upon seeps and vents. An expert judgment approach (see for example, Teck et al., 2010) gathered the opinions of workshop participants to estimate the levels of impact of these activities on the structure and function in chemosynthetic ecosystems below 250 m (Table 3). Taking into account the overall intensity of direct impacts, the persistence of impacts, and the likelihood of an activity, the most severe threats to natural ecosystem structure and function at vents and seeps are currently the extractive industries (minerals at vents, oil, gas and methane hydrates at seeps) and the impacts of trawling fisheries at seeps. Certain scientific research activities (observatories and drilling) and commercial test drilling pose moderate threats; CO_2 sequestration would also have an impact on vent and seep ecosystem function, were it to take place in association with vent and seep ecosystems. Scientific sampling and Phase II commercial exploration are not without impact, but they are not exhaustive in the way that mineral extraction will be, nor do they disrupt the integrity of the ecosystem in the way that deep drilling, for example, might. All other activities considered even remotely plausible at vents or seeps were deemed at the time of this workshop to be relatively benign. Certain exogenous effects on vent and seep ecosystems were also considered; of these, ocean acidification was considered most likely to affect ecosystem health. Another assessment by deep-sea biologists (Ramirez et al., submitted) ranked factors associated with climate change (warming, stratification, circulation, acidification) as the largest threats to vent and seep systems.

A key issue is the relative scale of natural and human-induced disturbance in vent and seep systems. Vents are located in volcanic systems and thus may be subject to catastrophic disturbance from volcanic eruptions that repave the seabed and reset the hydrothermal cycle of a vent ecosystem. The frequency and extent of seafloor eruptions are poorly understood in most places. Ridge systems in the eastern Pacific, where volcanic eruptions have been documented and studied, are exceptions. The general view is that organisms colonizing active hydrothermal vents are adapted to persist despite local extinctions that may occur at frequencies similar to the generation time of the dominant taxa through dispersal of propagules (planktonic larvae, mobile juveniles and adults). If the basic scale of human impact is less than or equal to that of an active vent field, as seems to be the case at least for initial effort to extract seafloor massive sulphides, then this areal impact would be comparable to that of a natural volcanic eruption. However, the cumulative impact of extracting multiple active vent fields in a manner that compromises connectivity and the ability of species to persist has the potential to jeopardize biodiversity.

Seeps may also be subject to catastrophic events, depending on the geological setting, as in the case of subsidence (for example, the Storegga slide), shifting fluid flow, or subduction earthquakes and mass wasting, but the frequency of such events is poorly known for most seep systems. The general view is that organisms colonizing seeps are adapted to relatively stable habitats where local extinctions are much less frequent than the generation time of the dominant seep taxa. The impact of an intensive trawling event on seep ecosystems seems likely to persist for extended periods, but to date there have been no time-series studies of the environmental impacts of trawling on seep ecosystems, though extensive fishing activity at seep sites has been documented (Baco et al., 2010).

Activities in the deep sea and exogenous effects are numerous, and they differ qualitatively in attributes such as: the likelihood of the activity at vents and/or seeps; the overall intensity of direct impact; the spatial scale, duration, and frequency of the activity; the persistence of the impact after the activity has ceased; and the probability of accidental events that would cause catastrophic environmental damage (Table 3). Of the activities considered, only extraction of seafloor massive sulphides at vents and bottom-trawling fisheries at seeps have both high likelihood and high impact; oil and gas extraction at seeps and certain types of scientific research at vents and seeps have high likelihood but low to moderate impact. Gas hydrate extraction at seeps is on the horizon (there is a moderate to high likelihood of this activity in the near future), but when and where it does take place, the overall intensity of direct impact was deemed to be high.

Table 3. Activities and exogenous effects in the deep sea at >250 m water depth with expert assessment of the characteristics of their impact on chemosynthetic ecosystems

Activity	Nature of impact	Likelihood of activity at seeps or vents (globally)	Overall intensity of direct impact
Direct commercial activities			
Exploration for commercial resources			
Phase I: exploration and prospecting	Noise and light (L-M), pressure wave (L), some bottom contact (L), removal of organisms and substrata (L-M), sampling fluids (L-M), habitat disturbance (L), plume generation (L)	High	Low
Phase II: exploration and prospecting, including environmental impact assessment	Removal of organisms and substrata (H), sampling fluids (L-M), habitat disturbance (H), plume generation (L), noise and light (L-M)	High	Low
Test drilling	Removal of organisms and substrata (H), habitat disturbance (H), plume generation (L-M), noise and light (L-M)	High	Low
Extraction of commercial resources			
Extraction - seafloor massive sulphides (vents)	Removal of organisms and substrata (H), habitat disturbance (H), plume generation (L-M), noise and light (L-M)	High	High
Extraction - gas hydrates (seeps)	Habitat disturbance (H), loss of habitat heterogeneity (H), sediment deposition (M-H), catastrophic mass wasting (M-H)	Moderate to high	High
Extraction - oil and gas (seeps)	Habitat disturbance (H), loss of habitat heterogeneity (H), sediment deposition (M-H)	High	Low to moderate
Geothermal or geochemical energy extraction (vents)	Removal of organisms and substrata (H), sampling fluids (L-M), habitat disturbance (H), plume generation (L-M), noise and light (L-M)	Low	Moderate
Other			
Bioprospecting (non-harvest-based)	Removal of organisms and substrata (H), sampling fluids (L-M), habitat disturbance (H), plume generation (L-M), noise and light (L-M)	High	Low
CO_2 sequestration	Death of organisms (H), habitat disturbance (H)	Low	High
Documentary film and other entertainment activity	Noise and light (L-M), pressure wave (L), some bottom contact (L)	High	Low
Tourism	Noise and light (L-M), pressure wave (L), some bottom contact (L)	Moderate	Low

	Spatial scale of activity[1]	Anticipated duration of activity	Frequency of activity at a site	Persistence of impact after activity has ceased[3]	Probability of accidental event (e.g. spill) to cause significant environmental damage
	Regional	Days	Moderate	Short	Low
	Regional	Months to years	Moderate	Short	Low
	Point	Days to months	Low	Intermediate	High?
	Local	Years	NA (one-time use)[2]	Short to intermediate	Low
	Regional	Years to decades	NA (one-time use)	Long	Moderate?
	Local	Years to decades	Na (one-time use)	Long	Moderate to high
	Local	Years	Low	Intermediate	Low to moderate?
	Local	Days	Moderate	Short	Low
	Local	Decades or more	Low	Long	Low?
	Local	Days	Low	Short	Low
	Local	Days	Moderate	Short	Low

Table 3. Ctnd...

Activity	Nature of impact	Likelihood of activity at seeps or vents (globally)	Overall intensity of direct impact
Indirect commercial activities			
Fishing activities			
Fishing – mid-water trawling	Removal of organisms (fish, others) (H), waste disposal (?)	Moderate	Low
Fishing – set nets	Removal of organisms (H), waste disposal (H)	Low	Low
Fishing – bottom trawling (seeps)	Removal of organisms (fish, others) (H), bottom contact/habitat disturbance (H), waste disposal (L), alters habitat geochemistry (H)	High	High
Fishing – bottom trawling (vents)	Removal of organisms (fish, others) (H), bottom contact/habitat disturbance (H), waste disposal (L), alters habitat geochemistry (L)	Low	High
Fishing – traps	Removal of organisms (H), bottom contact (L), waste disposal (L)	Low	Low
Fishing – long line	Removal of organisms (fish, others) (H), some bottom contact (H), waste disposal (L)	Low	Low
Extractive activities			
Mining cobalt crust	Removal of organisms and substrata (H), habitat disturbance (H), plume generation/ sediment deposition (M), noise and light (L-M)	Low	Moderate to high
Mining nodules	Removal of organisms and substrata (H), habitat disturbance (H), plume generation/ sediment deposition (M), noise and light (L-M)	Low	High
Oil and gas extraction (vents)	Indirect impacts due to sediment plumes (L-M), worst-case scenarios (H)	Low	Moderate
Other activities			
Waste disposal	Bottom contact/habitat disturbance (H), substratum for colonization (L), chemical/ toxic effects (?)	Moderate	Low to moderate
Shipping	Noise (?), waste disposal (pollution, M-H)	High	Low
Cables	Habitat disturbance (L; H if dragged for repair or removal)	High	Low

	Spatial scale of activity[1]	Anticipated duration of activity	Frequency of activity at a site	Persistence of impact after activity has ceased[3]	Probability of accidental event (e.g. spill) to cause significant environmental damage
	Local	Hours	Moderate	Short to intermediate	Low
	Local	Hours	Low to moderate	Short to intermediate	Low
	Local	Hours	High	Intermediate to long	Low
	Local	Hours	Moderate	Short	Low
	Point	Hours	Moderate	Intermediate	Low
	Point	Hours	Moderate	Short to intermediate	Low
	Regional	Years	NA (one-time use)	Long	Low
	Regional	Years to decades	NA (one-time use)	Intermediate to long	Low
	Local	Years	NA (one-time use)	Intermediate to long	High?
	Point to local	Months to years	Moderate	Long	Low
	Local	Hours to days	High	Short	Low
	Local	Years	Low	Long	Low

Table 3. Ctnd...

Activity	Nature of impact	Likelihood of activity at seeps or vents (globally)	Overall intensity of direct impact
Academic scientific research			
Observatory	Removal of organisms (H), habitat disturbance (H), plume generation (L-M), noise and light (L-M), scientific waste (L)	High	Low to moderate
International drilling program	Removal of organisms (H), habitat disturbance (H), plume generation (L-M), noise and light (L-M), scientific waste (L)	High	Low to moderate
Direct sampling	Removal of organisms and substrata (H), sampling fluids (L-M), habitat disturbance (H), plume generation (L-M), noise and light (L-M), scientific waste (L)	High	Low
Observation	Noise and light (L-M), pressure wave (L), some bottom contact disturbance (L)	High	Low
Acoustic surveys	Noise (L)	High	Low?
Exogenous effects			
Ocean acidification	Larval development, microbial community affected, physiological responses to low pH	High	Low to moderate
Global climate change	Alteration of environment, influence on current regimes (affect dispersal), stratification/water masses (food availability)	High	Unknown
Geoengineering	Alteration of environment/habitat, change in community composition/diversity (via altered food input)	Low	Low
Military activities	Unknown; presumed to be acoustic impacts (L-M), potential geochemical energy extraction (M?)	Low	Unknown

[1] *Spatial Scale (maximum dimension per unit activity): Point (<100 m); Local (<1,000m); Regional (kilometers); Global (basin-wide or more)*

[2] *Assumes these fossil deposits are completely exhausted during a single 'activity'.*

[3] *Persistence of Impact: Short (up to a decade); Intermediate (decades); Long (centuries); does not take into account potential for effective mitigation or restoration activities. An alternative approach would be to assess the resilience of the system.*

Legend: Colour codes reflect severity of impact on a scale from dark green (low) = light green (low to moderate) = yellow (intermediate) = orange (intermediate to high) up to red (high). NA means 'not applicable'.

	Spatial scale of activity[1]	Anticipated duration of activity	Frequency of activity at a site	Persistence of impact after activity has ceased[3]	Probability of accidental event (e.g. spill) to cause significant environmental damage
	Local	Years to decades	Moderate	Intermediate	Low
	Local	Months to decades	Low	Short to intermediate	Moderate?
	Point	Years	High	Short to intermediate	Low
	Local	Days	High	Short	Low
	Regional	Days	Moderate	Short	Low
	Global	Decades or more	NA	NA	NA
	Global	Decades or more	NA	Long	NA
	Regional	Decades or more	Low	Long	NA
	Unknown	Unknown	Low	Unknown	Unknown

Notes for Table 3:

- We have accounted for impacts to the seafloor but have not taken into account other impacts, such as greenhouse gas emissions or water column impacts, associated with the listed activities when assigning "Overall Intensity of Direct Impact" values.
- In assigning "overall intensity of the direct impact" values, we have not taken into account environmental management strategies that could reduce the severity of an impact.
- Under "persistence of impact" we have taken into account the likely resilience of a site and its ability to recover following a disturbance.
- We have not taken into account the effect of cumulative impacts in assigning the "overall intensity of the direct impact" values.
- The table has not addressed indiscriminate activities (for example, long-line fishing) versus those that are more selective.

CHAPTER TWO

International Instruments to Protect Marine Biodiversity

2. INTERNATIONAL INSTRUMENTS TO PROTECT MARINE BIODIVERSITY

Instruments for conservation and sustainable development in marine systems are now integral parts of international, domestic and customary law. The 1982 United Nations Convention on the Law of the Sea[4] (referred to here as the "Convention" or "LOSC"), which entered into force on 16 November 1994, established the jurisdictional framework for the management of ocean space and defined the rights, duties and responsibilities of States with respect to the use of ocean space and ocean resources. The Convention addresses issues such as the delineation of maritime space, rights over marine resources, protection of the marine environment from pollution and other harmful effects, and conditions for the conduct of marine scientific research in all areas of jurisdiction.

One of the key prerequisites to effective spatial management is to understand the different jurisdictional aspects of maritime space, and to appreciate that different regimes apply within national jurisdictions, on the high seas, and in the Area – the seabed, the ocean floor and subsoil, beyond the limits of national jurisdiction. Deep-sea chemosynthetic ecosystems may be found entirely within national jurisdiction, on the outer continental shelf (which is under national jurisdiction although the overlying water column is subject to the regime for the High Seas), or in the Area. A special regime, elaborated in Part XI of the Convention and a related implementation agreement,[5] deals with the development of mineral resources in the seabed and subsoil of the Area beyond national jurisdiction. The Convention also establishes the International Seabed Authority (ISA) as the institution through which States Parties to the Convention are to organize and control prospecting, exploration and exploitation of mineral resources in the Area. Such activities may not be carried out without a licence issued by the ISA in accordance with its rules, regulations and procedures.

To date, the ISA has issued regulations governing prospecting and exploration for polymetallic nodules[6] (adopted 13 July 2000) and polymetallic sulphides[7] (adopted 7 May 2010). These regulations include requirements relating to environmental protection, including requirements for exploration licence holders to collect and report environmental baseline data, carry out environmental monitoring programmes under the supervision of the ISA, and to establish environmental baselines against which impacts from anticipated mining activities can be assessed. The ISA Legal and Technical Commission issues recommendations to guide licencees in performing these obligations and regularly reviews reports and data collected. These recommendations are periodically reviewed with the assistance of the scientific research community, industry representatives, and other stakeholders to ensure they are based on the best available knowledge and reflect current best practice.

A number of other international instruments are also relevant to the conservation of biodiversity in the marine environment. The Stockholm Declaration arising from the 1972 Stockholm Conference on Environment and Development laid the groundwork for acceptance of sustainable development as a core principle for the management of human impact upon the environment. The principle is reaffirmed and elaborated in subsequent declarations and instruments, including the Rio Declaration (1992) and the Convention on Biological Diversity (CBD; 1993). One of the main goals of the CBD is conservation of all biodiversity, recognizing that ecosystems, species and genes must be used for the benefit of mankind, but that this use should be accomplished without a long-term decline in biodiversity and irresponsible environmental damage. The Rio Declaration and the CBD support the 'Precautionary Principle', which shifts the burden of proof to those who wish to undertake or continue an activity that poses a threat of serious or irreversible damage. Further, the CBD endorses an ecosystem approach[8] as a preferred strategy for integrated and adaptive management to promote conservation and sustainable use. The CBD also promotes the use of area-based management tools and has adopted a set of seven scientific criteria to identify Ecologically and Biologically Significant Areas (EBSAs) in the global marine realm.[9] Delegates at the World Summit on Sustainable Development called for the establishment of representative networks of marine protected areas (MPAs) consistent with international law and based on scientific information by 2012 to promote conservation and management of the oceans.[10] Further, the UN General Assembly (UNGA), as part of its annual review of oceans and the Law of the Sea, has passed several resolutions regarding the protection of the ocean, notably resolutions UNGA 61/105 (2006)[11] and 64/72 (2009),[12] which set out to protect Vulnerable Marine Ecosystems (VMEs) from the damaging effects of bottom fishing. Hydrothermal vents, together with seamounts and cold-water corals, are cited as examples of VMEs in UNGA 61/105, which recognizes "the immense importance and value of deep-sea ecosystems and the biodiversity they contain." [13] Consistent with LOSC obligations, UNGA resolutions and decisions reached in the framework of the CBD, a number of regional arrangements have implemented measures for the protection of the marine environment, including the environment in areas beyond national jurisdiction. Examples of regional arrangements include:

- Regional Fisheries Management Organizations (RFMOs), which have a duty to conserve all species associated with and dependent upon the fisheries that they seek to regulate. Membership in RFMOs includes fisheries nations, but although membership is encouraged, and includes most major players, it remains voluntary. If a nation does not join an RFMO, its flagged vessels may still operate in an RFMO region, although they will not be recognized by the RFMO or assigned quotas. The responsibilities of RFMOs are outlined in various international agreements, including the FAO Code of Conduct for Responsible Fisheries and the United Nations Fish Stocks Agreement,[14] both adopted in 1995. Some RFMOs are moving towards taking an ecosystem approach to management, and some have enacted fisheries closures in areas beyond national jurisdiction in order to protect vulnerable marine ecosystems (VMEs).

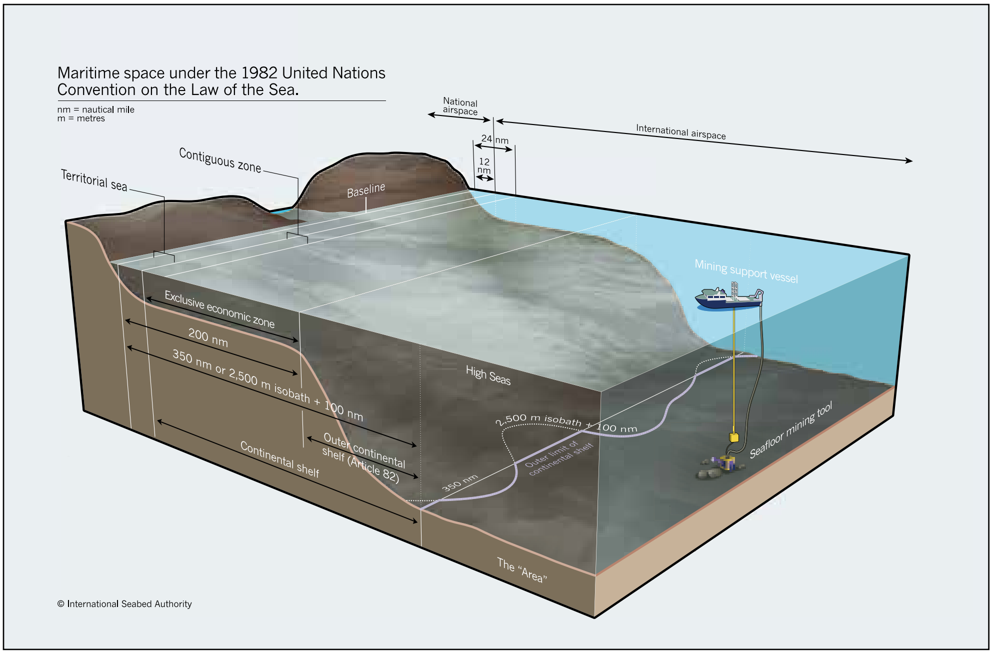
- Regional seas agreements that were often formulated to prevent and control pollution but now have begun to protect areas within and beyond national jurisdiction in order to protect biodiversity, such as:
    - o OSPAR Convention for the Protection of the Marine Environment of the North east Atlantic. [15]
    - o Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. [16]
- Multilateral agreements such as the Noumea Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, in which Parties have agreed to take all appropriate measures to prevent, reduce and control pollution in the Convention Area resulting directly or indirectly from exploration and exploitation of the seabed and its subsoil.[17]
- The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), which is applicable to the Antarctic marine living resources of the area south of 60˚ South latitude and to the Antarctic marine living resources of the area between that latitude and the Antarctic convergence which form part of Antarctic marine ecosystem.[18]

In addition, some of the principal stakeholder groups (scientists and the mining industry) have drafted codes of conduct related to environmental protection:

InterRidge. InterRidge is a non-profit international organization that pools the resources of its member countries to drive oceanic ridge research forward in a way that is cost-effective, cooperative and responsible. The InterRidge Statement of Commitment to Responsible Research Practices (http://www.interridge.org/IRStatement) at deep-sea hydrothermal vents affirms the commitment of the InterRidge community to responsible research. Glowka (2003) reviews the motivations and process that led to the code of conduct for marine scientific research at hydrothermal vents. The OSPAR regional seas agreement for the north-east Atlantic (noted above) has also adopted a scientific code of conduct (2008).

International Marine Minerals Society (IMMS). The IMMS is a professional, non-profit society whose members share a common interest in marine minerals to meet world demands for strategic minerals. The IMMS draft Code for Environmental Management of Marine Mining (http://www.immsoc.org/IMMS_code.htm) outlines environmental principles for the marine mining industry and operating guidelines that can serve as a basis for environmental management plans (Jones and Morgan, 2003; Verlaan, 2010).

Figure 1. Maritime legal zones: Territorial Seas (TS; 0-12 nautical miles); Contiguous Zone (CZ; 12-24 nm); and Exclusive Economic Zone (EEZ)



Source: International Seabed Authority.

[4] *United Nations Convention on the Law of the Sea of 10 December 1982, UNTS, vol. 1833, p. 3. As of 17 December 2010, 160 States and the European Union were parties to this Convention.*

[5] *Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, UNTS, vol. 1836, p. 3. As of 17 December 2010, there were 140 parties to this Agreement.*

[6] *ISBA/6/A/18, 13 July 2000.*

[7] *ISBA/16/A/12/Rev.1, 7 May 2010.*

[8] *Fifth meeting of the Conference of the parties to the Convention on Biological Diversity, Decision V/6 Ecosystem approach (2000).*

[9] *Ninth meeting of the Conference of the parties to the Convention on Biological Diversity, Annexes I and II of Decision IX/20 Marine and coastal biodiversity.*

[10] *Agenda 21, Section 2.17.*

[11] *A/RES/61/105, Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments. Adopted without a vote on 8 December 2006.*

[12] *A/RES/64/72 (2009), Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments. Adopted without a vote on 4 December 2009.*

[13] *A/RES/61/105, paragraph 80.*

[14] *Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks. As of 17 December 2010, there were 78 parties to this Agreement.*

[15] The OSPAR Convention was opened for signature in 1992 and entered into force on 25 March 1998. It replaces the former Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, 1972 (the "Oslo Convention") and Convention for the Prevention of Marine Pollution from Land-Based Sources (the "Paris Convention").

[16] Convention for the Protection Of The Mediterranean Sea Against Pollution, signed 16 February 1976, in force 12 February 1978 (revised in Barcelona, Spain, on 10 June 1995 as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean).

[17] Article 8. The Convention for the Protection of Natural Resources and Environment of the South Pacific Region (Nouméa Convention, or SPREP Convention) was adopted on 24 November 1986 and entered into force on 22 August 1990. It obliges Parties to endeavour to take all appropriate measures to prevent, reduce and control pollution from any source and to ensure sound environmental management and development of natural resources, using the best practicable means at their disposal, and in accordance with their capabilities. The South Pacific Regional Environment Programme (SPREP) serves as the Secretariat for the Convention.

[18] Article I, paragraph 1.

CHAPTER THREE

Protected Chemosynthetic Ecosystems

3. PROTECTED CHEMOSYNTHETIC ECOSYSTEMS

A limited number of chemosynthetic ecosystems are partially protected by measures put in place to protect the seafloor in general. For example, the Kermadec Benthic Protected Area in New Zealand is closed to bottom fishing, including at vent sites, but does not protect vent sites from other activities, such as mining. There are currently four specifically protected chemosynthetic ecosystems (all are vent ecosystems) in areas under the national jurisdiction of Canada, Mexico, Portugal and the United States. Each has different management goals and is specifically designed to achieve those goals. A brief description of each protected area is provided here to illustrate the range of precedents established by coastal States with regard to the conservation of these systems in waters under national jurisdiction.

Canada: The Endeavour Hydrothermal Vents MPA. The Endeavour Hydrothermal Vents MPA is located in the northeast Pacific Ocean at 2,200 m depth, 200 km southwest of Vancouver Island, Canada. The Endeavour MPA is 4 x 6 nautical miles (82 km^2) in area, encompassing five vent fields and includes features such as black smoker chimneys and massive sulphide edifices, areas of surrounding diffuse flow, and a high biomass of vent-endemic invertebrates, including 12 species not known elsewhere. The fields span a range of hydrothermal venting conditions characterized by different water temperatures and salt content, mineral chimney morphology and animal abundance. Temperatures associated with the black smokers are typically in excess of 300˚C. The flanks of the chimneys and the surrounding seawater support an abundant fauna that forms a mosaic community whose composition is constantly changing in response to shifting temperature and chemical conditions. Since their discovery in 1982, the Endeavour Hydrothermal Vents have been a focus of research by Canadian and international scientists. The Endeavour MPA was created to set the area aside for scientific research, which is monitored by a Management Committee to mitigate use conflicts and environmental disturbance caused by research. In order to safeguard the pristine nature of the area and permit long-term observations of natural change and response to natural disturbances, the management plan includes provisions covering, among others, the zoning of sampling and 'observation' only.[19]

Mexico: The Guaymas Basin and Eastern Pacific Rise Hydrothermal Vents Sanctuary. The Guaymas Basin and Eastern Pacific Rise Hydrothermal Vents Sanctuary, established by Mexico in 2009, includes 1,456 km^2 of benthic habitat and the water column up to 500 m below the sea surface (thus avoiding conflict with the fisheries industry). The Guaymas Basin hydrothermal vents protected area sector (477 km^2) is located in the Gulf of California at a depth of ~ 1,800 m. In contrast with other oceanic rift zones, the Guaymas hydrothermal vents develop over a deep sedimentary layer. The Eastern Pacific Rise hydrothermal vents protected area (979 km^2) is located at 21°N at a depth of around 2600 m and is an area that has been a stable spreading zone for the last 4 million years. Both sectors present distinct faunal assemblages. This MPA was created for scientific research. A technical advisory council to support governmental management planning is pending.

Portugal: The Azores Hydrothermal Vent MPAs. The hydrothermal vents of the Azores lie along the slow spreading Mid-Atlantic Ridge (MAR). To date there are Six identified hydrothermal vent fields with chemosynthetic fauna (Menez Gwen, Lucky Strike, Ewan, Menez Hom, Saldanha and Rainbow) have been identified before at depths varying from 850 m to around 2,300 m (Santos & Colaço, 2010), and a seventh rather shallow field, the D. João de Castro Seamount (Cardigos et al., 2005; Santos et al., 2010), with macro species equivalent to those found in coastal and seamount areas. All seven fields are included on the Azores Marine Park, which was created in 2007. Lucky Strike, Menez Gwen and Rainbow and D. João de Castro are included in the OSPAR MPA network. D. João de Castro has been part of the Natura 2000 network since 2002, and Lucky Strike and Menez Gwen since 2009. All fields are classified under the reef category of the EU Habitats Directive. Biodiversity (with around 70 species) and biomass is greatest at the Lucky Strike site (Desbruyères et al., 2001); Lucky Strike and Menez Gwen communities are dominated by the vent mussel Bathymodiolus azoricus, while at the Rainbow vent field, communities are dominated by swarms of the shrimp Rimicaris exoculata. All sites are considered to be part of the same biogeographic province (GOODS 2009). The frequency of tectonic and volcanic events that can disrupt the pathways for vent fluids are lower in this slow-spreading ridge system, thus resulting in greater temporal stability in the location and activity of the vent fields (Copley et al., 2007). Significant changes in population size and habitat extent are not expected, unless a major geological phenomenon happens or vent fluid activity changes. Given the relative geochemical and biological stability of the fields, their management as MPAs accommodates different scientific interests, from long-term, passive observation to experimental studies. The areas composing the Azores Marine Park, and all the protected areas beyond the territorial sea, are classified under IUCN criteria. Lucky Strike (288 km^2) and Menez Gwen (95 km^2) have zoning plans ranging from 'full protection' (Cat. I) to 'sustainable exploitation' (Cat. IV and VI), while Rainbow, a smaller vent field, is only classified under IUCN category IV. Lucky Strike has also been selected as a target field for the installation of the long-term seafloor MoMAR observatory (Santos et al., 2002; Person et al., 2008). Spatial and management planning takes this objective into special consideration (Santos et al., 2003). A summary of the management process and objectives may be found in Chapter 7.

The first national MPA under the high seas, Rainbow, has been proposed by Portugal, initially in the context of the OSPAR Convention (Ribeiro, 2010). Rainbow is a hydrothermal field on an area of the claimed Portuguese outer continental shelf beyond the 200 nautical mile limit.

United States: Mariana Trench National Monument. The Mariana Trench National Monument encompasses ~250,000 Km^2 of the Pacific Ocean in United States waters. Its protected status was designated by executive order of President George W. Bush under the Antiquities Act of 1906. The monument includes a series of active undersea volcanoes and hydrothermal vents. Active mud volcanoes, the Champagne Vent that produces almost pure liquid carbon dioxide, and the Sulfur Cauldron, a pool of molten sulfur, are among the natural wonders of this new monument. Fishing, mining and other human activities are barred from the Monument. [20]

Other protective measures (USA)

Seep communities are protected from impacts caused by oil and gas extraction activities in the Gulf of Mexico by the Department of Interior's Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly the Minerals Management Service). Buffer distances for all activities with a potential impact on seep habitats, including drilling discharges and anchor placement, are imposed on all oil and gas activities through industry leasing regulatory instruments. These buffer distances have been developed and increased over time through an adaptive management approach using a variety of field studies (Boland 2010).[21] Prior to the Deep-Water Horizon well-head failure, there had been no indication of significant impacts on Gulf of Mexico chemosynthetic seep communities, including some that have been studied intensively over a period of nearly 25 years. Recent submersible operations reveal oil layers coating seep surfaces in the vicinity of the blow-out site.

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[19] *See: http://www.dfo-mpo.gc.ca/oceans/marineareas-zonesmarines/mpa-zpm/pacific-pacifique/factsheets-feuillets/endeavour-eng.html.*

[20] *See http://georgewbush-whitehouse.archives.gov/news/releases/2009/01/20090106-2.html.*

[21] *For discharges related to drilling (discharged near the surface), this distance is 2,000 ft (~610 m) from the location of any "potential" chemosynthetic community. The potential is determined by the evaluation of remote sensing data, primarily 3D seismic extraction of seabed reflectivity anomalies. In the same way, anchor impacts must be buffered by at least 250 ft ~76 m). If proposed anchors are proposed within 250 (~76 m) and 500 ft (~152 m) of a seep, detailed maps are required to show the exact location of anchors after their placement. Biological review for deepwater communities is conducted for all plans submitted for water depths below 300 m (~984 ft). This includes all cases, even when NEPA determinations called "Categorical Exclusions" (which have incorrectly been labeled as "exclusions" or "waivers" in the media). This deep-water review was performed on the Deep-Water Horizon exploratory plan as well in Block MC 252. This policy appears in Notice to Lessees, NTL 2008-G40 http://www.gomr.boemre.gov/homepg/regulate/regs/ntls/2009NTLs/09-G40.pdf. These are regulatory instruments that essentially clarify the interpretation of existing broader scale regulations, which can be updated and modified relatively easily, in comparison with Code of Regulations, Subparts etc.*

CHAPTER FOUR

Urgency, Opportunity and Precedent

4. URGENCY, OPPORTUNITY AND PRECEDENT

From the moment of their discovery, chemosynthetic ecosystems have held intrinsic scientific value as systems of importance as they help us understand a number of topics, including fundamental properties of ocean chemistry, ore formation, biological adaptations to physical and chemical extremes, global biodiversity and biogeography, and the origin of life on Earth and elsewhere in the Universe. Our understanding of vent and seep ecosystems is, however, fragmented due to the relative inaccessibility of these ecosystems and the necessity of using advanced and expensive submarine technologies to study them.

At the same time that the scientific community is involved in studying chemosynthetic ecosystems, other sectors are either engaged in, or planning for, activities that could impact on these ecosystems. For seep systems along continental margins, the most urgent need for integrative spatially-based management is to pay attention to the direct and indirect impacts of ongoing trawling and long-line fishing, and the extraction of oil and gas. Because seeps are associated with continental margins and thus generally territorial waters and exclusive economic zones, they should be included in emerging national marine spatial management plans. For vent systems, we need to implement scientific and legal measures to minimize the impact of proposed seafloor massive sulphide mining (Halfar and Fujita, 2007). The ISA is the regulatory body for mining activities for vent ecosystems in areas beyond national jurisdiction. In contrast to the history of development of comprehensive conservation management plans for the oil, gas and fishing industries, which were designed and implemented after those industries were established, a narrow window of opportunity exists to establish regulatory frameworks for deep-sea mining and other extractive activities in areas beyond national jurisdiction through the work of the ISA before exploration leases and any mining-related activities begin.

The ISA recently adopted regulations governing prospecting and exploration for sulphides in areas beyond national jurisdiction. The first application for an exploration licence pursuant to these regulations has already been lodged and will be considered by the ISA in 2011. Additionally, marine mineral exploration licences have either been granted or lodged with a number of countries including New Zealand, Solomon Islands and Fiji. These actions, together with the ongoing exploration within the EEZ of countries such as Tonga and the likely emergence of a new deep-sea mineral extraction industry in the territorial waters of Papua New Guinea within the next few years (Hoagland et al., 2010), lend urgency to the formulation of policy that permits sustainable development of deep sea mineral resources in a manner that is consistent with LOSC obligations for the protection of the marine environment and the goals of the Convention on Biological Diversity. This is also an opportunity to undertake marine spatial planning in areas beyond national jurisdiction in a way that serves all stakeholders and establishes precedents to guide planning in national waters with regard to conservation of chemosynthetic ecosystems.

CHAPTER FIVE

Conservation Goal and Objectives for Chemosynthetic Ecosystems in the Deep Sea

5. CONSERVATION GOAL AND OBJECTIVES FOR CHEMOSYNTHETIC ECOSYSTEMS IN THE DEEP SEA

5.1 Conservation Goal

To protect the natural diversity, ecosystem structure, function and resilience of seep and vent communities.

Conservation objectives should relate to the concept of ecosystem-based management and to the dynamic structure and function of the ecosystems.

5.2 Conservation Objectives

(builds on CBD IX/20 Annex 2 and the CBD Ecologically and Biologically Significant [EBSA] Criteria):

Biodiversity

- *Ensure long-term maintenance of vent and seep ecosystems (noting those of particular scientific interest and value), including their habitat heterogeneity and biodiversity, particularly their genetic diversity, which allows for evolutionary novelty and adaptation to extreme environments.*

Connectivity

- *Ensure ecological connectivity within and between vent and seep communities and external functional linkages across ecosystems (for example, pelagic, non-chemosynthetic seafloor communities).*

Replication

- *Conserve multiple vent and seep ecosystems within management units to address uncertainty, natural variation, catastrophic events, limited scientific understanding and adaptive management.*

Adequacy / Viability

- *Ensure protected sites are of sufficient size and spacing through network design to allow for sustained ecosystems, including regional levels of biodiversity and ecosystem function, while accounting for management practicalities.*

Representativity

- *Ensure that multiple sites include examples of species, habitats and ecological processes that occur in a bioregion to account for uncertainty, natural variation and the possibility of catastrophic events.*

Sustainable Use

- *Incorporate measures that allow for well-managed human uses, such as energy and other resource extraction, fishing, education, research and bioprospecting – within and outside of vent and seep managed areas, when consistent with conservation goals.*

- *Provide scientific reference (control) sites with long-term monitoring to help differentiate the effects of direct human activities from natural variability and other indirect stressors (for example, ocean acidification and climate change, etc.).*
- *Maintain the potential of vent and seep ecosystems to provide future services (for example, industrial, medical and other benefits), as well as the evolutionary potential for biota to cope with change.*

CHAPTER SIX

Dinard Guidelines for Spatial Approaches to Conservation of Vent and Seep Ecosystems and Management of Human Uses

6. DINARD GUIDELINES FOR SPATIAL APPROACHES TO CONSERVATION OF VENT AND SEEP ECOSYSTEMS AND MANAGEMENT OF HUMAN USES[22]

6.1 *A PRIORI* CONSIDERATIONS

The following set of *a priori* considerations and recommendations provided a context within which workshop discussions were promoted.

- *Determine how spatial management approaches may be applied to the conservation and management of deep-sea vent and seep ecosystems.* These approaches are consistent with the spatial and temporal nature of vent and seep ecosystems and with human activities that may take place in these systems (for example, mining at vents, trawling at seeps).
- *Identify spatial management goals for vent and seep ecosystems.* Management goals should operate at different scales and levels; they will be most useful and meaningful if linked to particular laws, conventions and other instruments.
- *Develop broad design guidelines.* These guidelines should be general and applicable to different management contexts (international, national and regional). The guidelines should be based on conservation and management goals, and should be useful for countries and organizations that do not have the expertise and resources to develop their own specific guidelines.
- *Recognize that chemosynthetic ecosystems should be an element of the broader context of marine spatial planning.* The guidelines for the management of vents and seeps should be integrated with other spatial management needs (for example, for areas with multiple human uses and activities, such as mining and fisheries).
- *Inform the public and policymakers of the value of vents and seeps.* Use existing outreach portals that are widely available (for example, United States National Marine Protected Areas Center, Global Ocean Biodiversity Initiative) and develop new relationships, partnerships, mechanisms and materials as appropriate.
- *Increase knowledge and understanding of the impacts of the most habitat-destructive activities.* This includes identifying the types and levels of disturbance and the spatial scales of their effects.
- *Determine the key elements of the management process for the designation of areas and networks of areas to be developed to meet conservation goals, including stakeholder involvement.* A clearly defined process for the engagement of stakeholders is critical to the implementation of conservation practices.
- *Document and make available to the public any relevant information related to management planning in order to ensure transparent processes and decisions.* All stakeholders need to be aware of, and have the opportunity to contribute to, the development of management practices.

- *Highlight the need to improve our knowledge of the global distribution of vents and seeps – knowledge of the distribution of habitats over a range of scales is critical to network design.* In the absence of visual or chemical confirmation, geological and geophysical mapping and modeling can be used to predict the likely occurrence of habitats.
- *The past few decades have yielded discoveries that have transformed our understanding of the fundamental properties and variety of habitats of the Earth's biosphere.* Additional discoveries are extremely likely. Governance and management plans for the deep sea should facilitate the discovery of new ecosystems and biodiversity, and marine scientific research.

6.2 Marine spatial planning for conservation goals

Marine spatial planning allows for the creation of designated-use zones, such as Chemosynthetic Ecosystem Reserves (CERs). Well-designed CERs are a type of management area that should contribute to the conservation goal defined above. Principles for the design of CERs for vent and seep ecosystems should reflect fundamental characteristics of the deep-sea environment and its ecosystems, including the human component. In addition, the design of CERs should be integrated within broader schemes of marine spatial planning where they exist, and the broader goals of ecosystem-based management.

Policy conditions

- The management unit in which a CER network can be created must be at least large enough to achieve (even theoretically) the stated conservation goal and objectives and allow for adaptive management, including the creation of new, future CERs and the expansion of existing or established CERs.
- CERs should be selected so as to promote the integration of interests of multiple governance bodies and multiple regions of ocean ecosystems (including the pelagic realm) and within the context of other deep-water ecosystems (for example, coral reefs, seamounts and banks).
- A partial network of CERs (that is, one in which there may be gaps and only partial fulfillment of guidelines) can be created, provided there is a plan to adapt the network as more information and data become available. When creating partial networks, the precautionary principle should be applied: CERs should be created based on reasonable expectations of risk, and not be postponed if ecosystem disturbance is ongoing or imminent, even if detailed ecological and biodiversity data are lacking. A minimum effort should be defined to ensure that what is being set aside is representative of what is available without restriction outside the network. Cost-benefit analyses should be used to assist decision processes for network design.
- The management units that should be targeted early for the implementation of CERs are those for which ecological and human values

for protection are already known to be high and impacts to ecosystems exist or are likely to exist soon (including impacts from mineral resource exploitation and trawling).

An understanding of the spatial distribution of habitats and activity sectors is critical to marine spatial planning efforts. Datasets of the locations of the most likely extractive activities (for example, fisheries, high-grade ore deposits, areas of interest for bioprospecting) should be merged as they develop with spatial contexts of biogeography and jurisdictional responsibility.

6.3 Ecologically and biologically significant areas

The Convention on Biodiversity (IX/20 Annex 1) defines ecologically and biologically significant ares (EBSAs) by seven criteria:

1. uniqueness or rarity
2. special importance for life history of species
3. importance for threatened, endangered or declining species and/or habitats
4. vulnerability, fragility, sensitivity, slow recovery
5. biological productivity
6. biological diversity
7. naturalness

Many chemosynthetic sites meet these criteria and in addition may have particular scientific, historic or cultural characteristics that give them added value. Historic chemosynthetic sites are those that are also those of particular scientific value, having been studied scientifically for decades. Cultural sites may include long-used fishing grounds by artisanal fisheries (seeps). Cultural sites for vents are more difficult to identify; one example is where human remains have been placed on the seafloor (for example, the ashes of Dr. John Edmond, an MIT Professor, placed at the Snake Pit vent site on the Mid-Atlantic Ridge).

- Chemosynthetic areas that meet EBSA criteria or of particular scientific, historic or cultural importance should be considered as priorities for protection.
- An international group of experts – including representatives from competent authorities and affected stakeholder groups – should call for and evaluate information regarding the CBD EBSA criteria and areas of scientific, cultural or historical significance that should be considered for protection.

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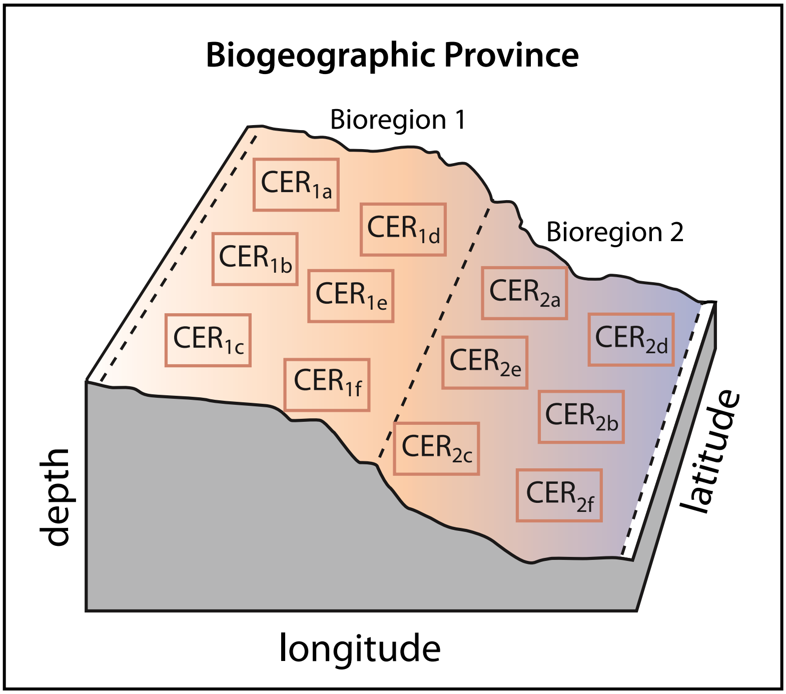
[22] *The 2010 Dinard workshop builds on the findings of the InterRidge-sponsored workshop in 2000 on Management of Hydrothermal Vents (www.interridge.org/files/interridge/Management_Vents_May01.pdf).*

6.4 Principles of design for CER networks

Principles of design for CERs must serve the conservation goals (see Section 5). These design principles should be applied within hierarchical regional frameworks comprising CER networks within all bioregions of Biogeographic Provinces (Figure 2).

Figure 2. Hierarchical regional framework: CER networks (a-f) within two bioregions (1, 2) defined by bathymetry within a biogeographic province



Note: CERs identified through the EBSA process (see Section 6.3).

Legend: Dashed lines indicate transition regions; shading reflects the gradient nature of faunal transitions.

6.4.1 Define the regional framework for protection of biodiversity

To achieve the central goal of protecting the breadth of biodiversity (from genes to ecosystems) in chemosynthetic ecosystems around the world, CER networks should be distributed globally where they are known or likely to occur, and should achieve conservation goals at multiple geographic scales that correspond to the natural distribution of taxa.

- Biogeographic provinces are the largest units across which conservation management goals should be comprehensive.
- Within biogeographic provinces, CER networks should be distributed across bioregions to achieve conservation goals.

There has been considerable progress in identifying major biogeographic provinces for vent systems, though the number and location of transition zones between provinces defined by species differences is not completely known. Working maps of vent provinces, subject to modification as exploration of the vent ecosystems continues, may be found in the CBD report on Global Oceans and Deep-Sea Habitats (GOODS) (2009; see also Van Dover et al., 2002). Biogeographic provinces for seep species remain to be defined. Until this information becomes available, existing knowledge of seep differentiation by depth and geographic area and large-scale oceanographic, bathymetric and geologic conditions can be used to approximate major biogeographic provinces for seeps and to define CERs.

Within biogeographic provinces, the characteristics of chemosynthetic ecosystems vary along geographic and bathymetric gradients (and perhaps within qualitatively different geological settings, for example, basalt vs ultramafic-hosted vent systems, or petroleum seeps vs mud volcanoes), resulting in identifiable and coherent bioregions.

- Bioregions more closely approach the natural scales of connectivity and thus represent the spatial scale of ecosystem-based management that is likely to be most useful for marine spatial planning and multiuse zoning.

Bioregions can be defined analytically as collections (i.e. clusters) of ecosystems with similar community structure (that is, species composition and relative abundance) and environmental conditions (for example, oceanographic, geologic).

While CER networks (and CERs themselves) may cross boundaries of biogeographic provinces, marine spatial planning to achieve conservation goals must take into account biogeographic provinces and bioregions.

6.5 Define CERs within bioregions

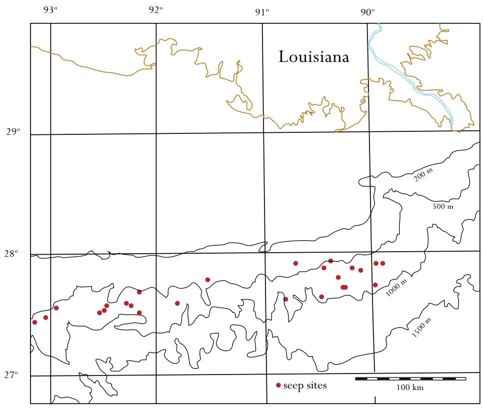
Distributed and replicated CERs within bioregions ensure that the diversity of chemosynthetic ecosystems (both geologic and biotic components) are considered and protected across the world ocean. The pattern of distribution of chemosynthetic sites within a bioregion differs depending on the geological setting, and ranges from semi-continuous habitats (for example, thousands of seeps along the continental slope of the Gulf of Mexico (Figures 3.1 and 4); a dozen or more sulphide fields in Manus Basin, Papua New Guinea) to dispersed habitats (for example, one known seep site on the entire Atlantic coast of the United States (Figures 3.2 and 4); vent sites separated by 100 km or more on the Mid-Atlantic Ridge).

6.5.1 Theory of size and spacing of CERs

Strategies for the design of CER networks depend on knowledge of the distribution of habitat, but a lack of knowledge is not a reason to do nothing, especially if human impacts are imminent or ongoing. In circumstances where little is known about the distribution of habitats and risks of impacts are high, the precautionary principle applies, wherein CER size and spacing should be based on the most basic and conservative principles.

Geological, geochemical and ecological processes dictate the scale of distribution and dynamics of chemosynthetic ecosystems. The basic (quantum) unit of a vent or seep is a "site" (typically hundreds of meters to a few kilometers in maximum dimension; see Table 1), within which there may be a dynamic and heterogeneous mosaic of communities defined by characteristic species (for example, mussels, clams, snails, tubeworms) and at different stages of succession (including nascent through inactive sites).

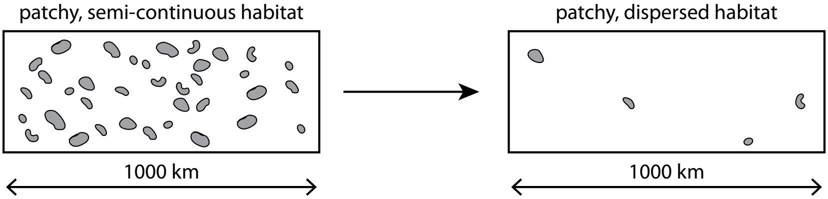
Figure 3.1 An example of patchy, semi-continuous distribution of chemosynthetic habitats: Seeps on the Louisiana Slope, Gulf of Mexico



Source: Macdonald et al., 1996.

Figure 3.2 An example of a patchy, dispersed habitat (as understood to date): Blake Ridge Seep – the only known seep site on the Atlantic seaboard of the United States

Figure 4. Two end-member distributions of chemosynthetic habitat. Note the continuum of distribution between the two habitats



At the spatial scale within a site, species diversity (with associated ecological function and interaction) is the collective diversity across the dynamic mosaic of communities, and the minimum size of an area necessary to protect the diversity of species within a site must therefore span the mosaic of habitats. Species-area curves can be constructed to identify the area that spans the collection of these largely sessile communities and the diversity of species at a site. Because most chemosynthetic taxa are attached or sessile as adults, adult movement is unlikely to be an important determinant of the size of a management area. This contrasts with the situation in shallow coastal marine ecosystems, where fishes or invertebrates may be highly mobile as juveniles and adults.

Most species in chemosynthetic ecosystems have life history stages adapted for dispersal by ocean currents (typically as larval stages, although some taxa may disperse as juveniles or even adults); many local populations associated with a habitat patch are thus reliant on replenishment by offspring produced at other habitat patches.

For the maintenance of apopulation within a single management area, Lockwood et al., (2002) argues for management area sizes of approximately twice the mean dispersal distance, while others (Botsford et al., 2001) argue for at least approximately one time the mean dispersal distance for self-sustaining populations. Species will persist if their mean dispersal distance is less than the linear spatial dimension of the management area (Botsford et al., 2007). Management area sizes of 4-6 km maximum dimension are reasonable for maintaining a self-sustaining population of short-dispersing species in coastal settings (Halpern and Warner, 2003; Shanks et al., 2003).

- Average dispersal success suggests that increasing patch size increases survivability for patch sizes up to two times the mean dispersal distance but after that, gains in survival accrue slowly for each additional unit area (Lockwood et al., 2002).
- Isolated patches require more protection (for example, larger CERs for complete larval recruitment/self-replenishment, bigger buffers) than semi-continuous patches.

Where feasible (for example, semi-continuous habitat distributions), networks of intermediate-sized (10 to 100 km^2) management areas will be more effective than fewer, large management areas, particularly if the networks include a variety of representative habitats (National Research Council, 2001; Halpern and Warner, 2003). Population persistence is not sensitive to management area spacing or dispersal distance if a network protects a minimum fraction of habitat (Botsford et al., 2001; Kaplan and Botsford, 2005; Almany et al., 2009). Across many invertebrate species, successful larval dispersal ranges from metres to hundreds of kilometers (usually fewer than 100 km), suggesting that networks of CERs may be connected for some species over broad ranges of distances (for example, one to 50 km; Jones et al., 2009). For suites of species with broad ranges in dispersal distances, Shanks et al. (2003) recommend a minimum management area size of ~6 km, and a management area spacing of 10 to 20 km. Almany et al., (2009) do not provide a good general model for management area spacing for non-coral reef communities. They assume that all individual species have variable dispersal scales ranging from <1 to >100 km. Their 50-km spacing is also combined with the recommendation or assumption that individual CERs are relatively large (that is, containing a large proportion of critical habitats and ecological processes needed to sustain multiple species, and populations large enough to minimize genetic drift and inbreeding). These assumptions are very limiting, and the first relating to variable dispersal distances within species, and are very unlikely to hold true for all vent and seep species (especially species with planktotrophic development, of which there are many at vents). A wide range of between-management area distances is more likely to be successful than one with uniform spacing (Carr et al., 2003; Kinlan and Gaines, 2003; Palumbi, 2003; Shanks et al., 2003; Halpern and Warner, 2003).

6.5.2 Guidelines for size and spacing of CERs

Precautionary and consultative approaches to achieving management goals are recommended for semi-continuous and dispersed chemosynthetic ecosystems, and for habitat distributions that lie between these two end-members (Figures 3 and 4).

Strategies:

Semi-continuous habitats are amenable to conservation methods that aim to protect representative samples of habitats.

Widely dispersed habitats should be considered more like ecological habitat islands and potential "stepping stones". This suggests that extractive, scientific and conservation values could be in conflict under this condition. Management of each site must be considered individually, and a collaborative process between industry, scientists and conservationists should be fostered. In either semi-continuous or dispersed habitat conditions (Figure 3), there needs to be an understanding of what is known and what is not known (and what we are capable of finding out, etc.).

CER dimensions:

For semi-continuous habitats that are distributed over a large area (for example, hundreds of square kilometers), the size of CERs should exceed the mean dispersal distance of any demographically isolated population in the habitat.

Dispersed chemosynthetic habitats vary in size and temporal dynamics, but as understood today, tend to be long-lived (active fluid flux for hundreds to thousands of years), with a maximum dimension of 1 km or less. Where these sites are established as CERs, the CERs should comprise the entire habitat, plus a buffer zone, to ensure that there is comprehensive management of the site. For example, a potential CER might be the active TAG mound on the Mid-Atlantic Ridge (~100-150 m diameter) or the Blake Ridge seep (~100 m max dimension) on the continental shelf of the eastern seaboard of the United States. It is recommended that sites such as these be CERs in their entirety, and that they have a buffer zone.

Buffers:

All CERs should be buffered to prevent detrimental impacts affecting ecosystem structure and function.

Spacing:

Spacing of CERs within a network of semi-continuous patches should mimic the natural distribution of distances between habitat patches, if known. If the distribution is unknown, the distance between CERs should incorporate a variety of distances, reflecting known and expected patchiness.

Networks:

CERs should be organized as one or more networks within a Bioregion and should take into account the potential for directional dispersal and for optimization of the ability of each management area to serve as a source and sink for recruits, when the appropriate data are available.

6.5.3 Replication of management area networks across a bioregion

Conservation target:

Well-studied areas

These are areas where 90 per cent or more of the chemosynthetic sites within a region have been located and imaged. At least 30 per cent of the available targeted (vent or seep) habitat/ecosystem should be managed for conservation purposes (based on 2010 ISA recommendations).

Poorly studied areas

Where the chemosynthetic habitat targeted for protection has a patchy or dispersed structure (as is the case of many vent ecosystems), and distribution patterns will remain largely unknown prior to the proposed activity, it is recommended that a substantial portion (greater than 50 per cent) of the management area likely to contain the targeted habitat/ecosystem should be placed in a network of CERs.

- *CER networks should be replicated across a bioregion to increase their and to reduce the risk of losing biodiversity and ecosystem function due to local or larger-scale perturbation events across the entire bioregion. Ideally, the multiple CER networks within a bioregion would be designed to function as a larger interconnected network spanning the entire bioregion (Halpern and Warner, 2003).*

The greater the number of distributed CERs, the more likely the full breadth of biodiversity will be represented across the network within a bioregion and the biogeographic province. The OSPAR agreement 2006/3 notes that replication

- Spreads risk against damaging events and long term change affecting individual CERs;

- Ensures that natural variation in the feature is covered (either at a genetic level within species or within habitat types);
- Increases the number of connections between sites and enhance connectivity in the network; and
- Allows the establishment of scientific reference areas.

It is suggested that one more be added to this list; namely that replication:

- Takes account of uncertainty in the identification of habitats and biotic communities, so that the greater the uncertainty, the more replication is required to ensure the full breadth of habitats and ecosystem functions are likely to be protected.

Assessment of replication is somewhat complex. It is related to the concepts of ecosystem redundancy and resilience, which have been intensively discussed for several years (Anderies et al., 2006).

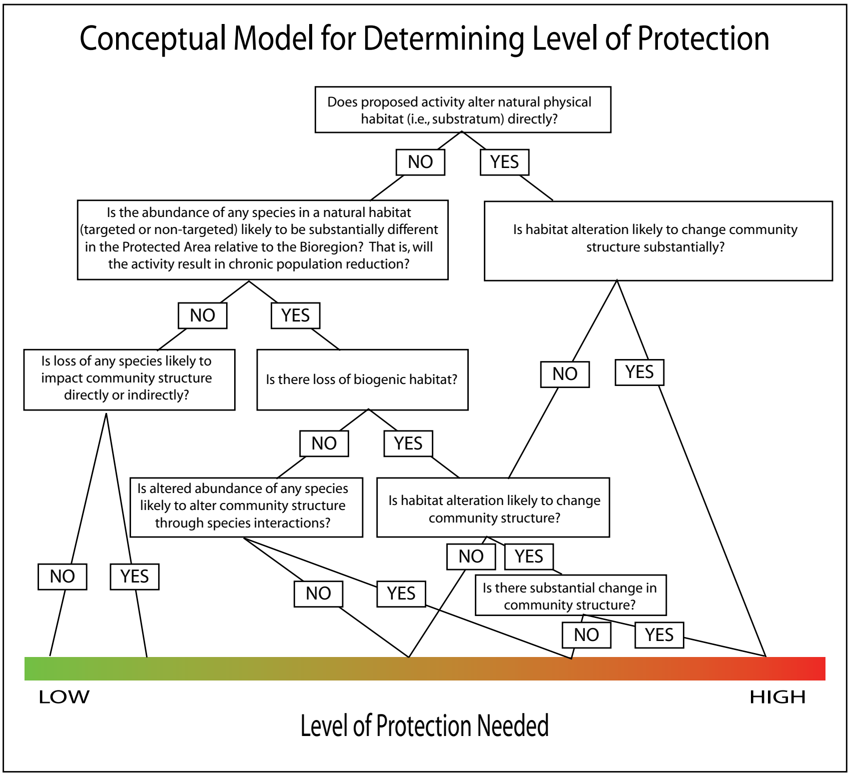
6.5.4 Define human uses and levels of protection

A central design criterion to consider is whether certain human activities may be allowed within a CER, and if they are allowed, what level of ecosystem disturbance will be permitted. The most protective CERs are those that limit all human access. This is likely to be feasible where sites are semi-continuously distributed, but perhaps not possible where sites are widely dispersed. Such a high level of protection could undermine the ability to use these CERs to understand unperturbed ecosystems and to apply adaptive management principles. The next greatest level of protection restricts any long-term alteration of the chemical or physical habitat (geologic, oceanographic), including alteration of habitats created by organisms (for example, corals, sponges, mussel beds and microbial mats). Other considerations in determining the level of protection afforded by a CER that has multiple uses include the number of species affected, the ecological roles of those species in the ecosystem, and the extent to which a population and its genetic diversity would be altered.

- *Key questions to be addressed when considering multiple activities within a management area are "How different will the ecosystem become in comparison to an ecosystem in similar habitat that is completely protected from human activities, and how much difference is acceptable?"*

Decision trees for answering this question qualitatively are useful when ranking the level of protection afforded by a CER that has multiple uses (Figure 5).

Figure 5. Conceptual model for determining the level of protection afforded by multi-use activities in a CER



Adapted from the Marine Life Protection Act (MLPA) Science Advisory Team (2010).

6.6 Management of CERs

6.6.1 A two-level approach for identifying CERs

As noted above, site selection of CERs will ultimately answer to network level considerations such as representativity and replication. This suggests a two-level approach whereby: 1) individual sites of extraordinary value are selected; and 2) networks incorporate these and other sites as required to achieve conservation management goals.

The separation of site- and network-level considerations was formalized by the Convention on Biological Diversity (CBD) decision XI/20, which adopted the seven criteria to identify EBSAs (that is, sites of particular interest) and which further adopted five criteria to create representative networks of protected areas (CBD 2008; IX/20, annexes 1 and 2, respectively). In Annex 3 of this CBD decision, four initial steps are suggested for the development of networks of protected areas. Paraphrasing CBD language, these four steps are: a) identify important areas; b) choose a classification system that allows an assessment of their representativity; c) select amongst these sites members of a tentative network, filling in gaps with additional sites as necessary; and d) assess the adequacy of the sites and the network. These suggested CBD steps are included in the discussions above. The first step of consideration, EBSA site identification, stands apart from the other three, which are network-oriented.

Level 1. Selection of CER sites of extraordinary value: Vent and seep sites are likely to already qualify as EBSAs according to the CBD criteria; selecting candidate CERs amongst them will require other considerations such as additional scientific value or choosing sites that are in some way exceptional (for example, an unusually large and/or dense grouping of features). Such extraordinary sites would by their very special nature recommend themselves for protection. Such sites could (and usually should) be selected before mineral exploration leases or permission for other activities are granted, as the need for their protection is *prima facie* apparent.

Level 2. Selection of a CER network: Choosing sites for a CER network will to a large degree depend on the distribution and nature of existing and proposed human activities and their economic values in the planning area. That is, if a given site is identified as valuable for a particular activity, such as mining, then other ecologically similar sites should be considered for protection whenever possible. Hence, this second stage is best taken within the broader context of planning for human activities, once the priorities of these activities are known and informed trade-offs can be made. Management considerations will differ greatly between vents and seeps (see section 7, below). Unlike seeps, vents are primarily the targets of a single activity with a high likelihood of high intensity impact (mining). Seeps are damaged collaterally as a result of other activities in the area, such as bottom fishing and oil and gas extraction. While the vent situation can conceivably be addressed through a single-sector planning process (for example, via the ISA), the seep situation is more complicated and would be best served through a multi-sector, maritime spatial planning process.

6.6.2 Account for uncertainty and new knowledge through adaptive management strategies.

There are significant knowledge gaps relating to the size of natural conservation units, connectivity, and other design criteria (see section 8), resulting in a high degree of uncertainty related to effective means of protecting chemosynthetic ecosystems. Similarly, there are uncertainties in other values of chemosynthetic systems (for example, local variations in size and commercial value of deposits or reservoirs).

- *A key design process is the employment of adaptive management strategies.*

Through monitoring and evaluation, the effectiveness of a design criterion (for example, size, spacing, allowed uses) can be compared among different levels of design (for example, smaller vs larger CERs) or environmental conditions. Replication of different levels of design criteria can be included in preliminary experimental networks to assess their relative effectiveness in achieving conservation goals. Upon assessment, design criteria may be altered to enhance the effectiveness of the entire network of CERs and to enhance resource utilization. An example of adaptive management applied to chemosynthetic communities in the Gulf of Mexico is provided in Boland (2010), where initial protection measures were designed to prevent direct impact, first using an avoidance policy while written instruments known as 'Notice to Lessees' were developed to serve as supplements to governance regulations. Following contracted studies of seep systems in the area, new avoidance criteria were established for 'potential' as well as documented seep communities. These criteria were further updated based on accumulation of new data.

6.6.3 Additional considerations

A number of process activities are critical to the effective development of CERs, including:

- *Consultation: Multi-stakeholder consultation (for example, oil, gas and mining industries, commercial and artisanal fisheries, scientists, conservationists) is needed during the design and implementation of CERs and of other responsible environmental management solutions for chemosynthetic ecosystems.*
- *Transparency: Open and timely access to non-proprietary environmental data and cross-sectoral information exchange is essential.*
- *Governance of CERs: Where CERs spatially overlap with areas managed under other frameworks (for example, MPAs in national waters or other marine spatial management frameworks), their management should, whenever practical, be integrated within a single governance structure.*

Where multi-use CERs are developed, there is a need for environmental impact assessments, monitoring strategies, and stop-action criteria:

- *Environmental Impact Assessments (EIAs) for activities likely to cause serious adverse effects on ecosystem structure and function should be required and should follow best practices, such as those being developed by the CBD and the ISA. Knowledge gained from EIAs should inform strategies of management area size, spacing and network design to achieve conservation goals.*
- *Monitoring strategies: Monitoring strategies should be designed to assess the impact of cumulative activities through space and time within CERs and managed area networks.*
- *Prescriptive criteria for 'triggers' to indicate the need for closer monitoring or cessation of activities that threaten conservation goals within management area networks should be in place before multi-use activities begin.*

6.6.4 Efficacy of management area networks

The ability of CER networks for deep-sea chemosynthetic ecosystems to achieve conservation goals is unknown, though experience in other ecosystems suggests that some success is reasonable to expect (e.g. Roberts et al., 2001; Halpern, 2003; Selig and Bruno, 2010).

- *CER networks designed by best practice guidelines and educated assumptions should include tests of whether protected sites perform as desired, both individually and as networks. This will require long-term monitoring of protected and exploited sites.*

CHAPTER SEVEN

Management Considerations

7. MANAGEMENT CONSIDERATIONS

As outlined in chapter 2 above, there are several instruments that effect the management and protection of vents and seeps. Management planning itself falls outside the remit of this report. Considerations feeding into the formulation of management plans will differ significantly for vents and seeps.

In the case of vents, seafloor massive sulphide (SMS) extraction is the single most likely foreseeable human activity for which the design principles provided in this report could apply. SMS mining is local and site-specific, on a scale of tens to hundreds of meters. Within a given jurisdictional region, management can be expected to consider sites for possible exploitation or protection as a combined question. Hence extraction activities would not be randomly displaced to another neighbouring site, should a particular site be protected. Rather, extraction would be limited to those sites for which permission has been explicitly provided within the context of effective environmental management.

With regard to seeps, instead of a single activity, there are a variety of human activities to be considered, each with differing characteristics and management frameworks. Those that have immediate potential to cause significant harm – most notably bottom fisheries, and oil and gas activities – generally operate on a scale of hundreds of metres to kilometres, and have the flexibility to shift their activities should a given seep site be protected. Hence, when protecting a given seep site, displacement of human activities should also be considered, since it is likely that the affected human activities (for example, bottom trawling or drilling an oil well) will shift to a neighbouring habitat. All this suggests that a more comprehensive management decision process is necessary; one that considers multiple human activities and the broader context of other regional ecological features, such as concentrations of corals, which are commonly found in regions similar to seeps.

CHAPTER EIGHT

Knowledge Gaps: Chemosynthetic Ecosystems

8. KNOWLEDGE GAPS: CHEMOSYNTHETIC ECOSYSTEMS

Through three decades of research, scientists have learned much about the basic properties of vent and seep ecosystems, but from a management perspective there are critical knowledge gaps, primarily: the degree of connectivity (including larval dispersal, settlement, recruitment, gene flow) among sites; the resilience of vent and seep systems to cumulative disturbance; and the effectiveness of mitigation and restoration strategies. At present, for example, there is very little understanding of source-sink dynamics and of what an effective network of protected areas might look like, except that the optimal network size and spacing will be different for vents and seeps and within vent and seep bioregions. These unknowns should not prevent emplacement of management strategies; they argue for a precautionary and adaptive approach to management.

To date, there are at least three critical gaps in our understanding of chemosynthetic ecosystems, namely:

- **Connectivity:** Knowledge of connectivity is critical if we are to understand the sensitivity of populations to the removal of one or more sources of larvae. Adaptive management allows for learning by doing, without ever knowing such details, but responsible management practices will be informed by interdisciplinary studies of larval ecology, ocean circulation and population genetics, but these studies are in their infancy.
- **Resilience to disturbance:** Knowledge of the resilience of chemosynthetic ecosystems, that is, their ability to sustain and recover from a perturbation and from cumulative impacts. Recovery times and trajectories following major disturbances are poorly known for most vent systems and especially for seep systems. Exceptions are observations of relatively rapid recoveries on the scale of years following volcanic eruptions at vent sites on the East Pacific Rise (9 50'N) and Juan de Fuca Ridge (Axial Volcano).
- **Effectiveness of management strategies.** The deep sea remains a relatively inaccessible place; strategies for mitigating loss of ecosystem structure and function or, once the persistence of an ecosystem has been compromised, effective means of restoring habitat structure and function, have scarcely been considered or evaluated for their cost-effectiveness.

Workshop participants considered the knowledge status for a number of other important characters of chemosynthetic ecosystems. These are listed in Annex IV.

CHAPTER NINE

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Annexes

Annex 1: Definition of terms used in the report

Adaptive management. A structured, iterative process of decision making that incorporates new information and achieves management goals by managing uncertainty and by reducing uncertainty over time through environmental monitoring and assessment. For example, as more specific information is obtained concerning habitat distribution, population connectivity and the scale of human impacts, the size and distribution of CERs may be modified to achieve management goals.

The Area. The seabed (that is, the ocean floor and subsoil thereof) beyond the limits of national jurisdiction, The Area is a legal term contained within the United Nations Convention on the Law of the Sea. See also "Areas Beyond National Jurisdiction" and "High Seas".

Areas Beyond National Jurisdiction (ABNJ). The seabed (that is, the ocean floor and subsoil thereof) beyond the limits of national jurisdiction and/or the water column beyond national jurisdiction; that is any portion of the sea that lies beyond national jurisdiction. See also "High Seas" and the "Area".

Authigenic carbonate. A carbonate precipitate structure (pebbles, rocks, boulders, mounds) typically produced by activity of anaerobic methane-oxidizing microbes at seeps.

Biodiversity. The diversity of life assessed at multiple levels, for example, ecosystem, habitat, community, species, population and genetic.

Biogeochemistry. A scientific discipline that studies the integration of biological, geological, chemical and physical process and reactions, with a focus on systems that may be driven by or have an impact on biological activity.

Biogeography. The distribution of species and assemblages over space and time, and the factors that influence these distributions.

Biogeographic province. A fundamental biogeographic unit characterized by broad-scale taxonomic similarities; turnover of major taxa is observed between provinces.

Bioprospecting. The search for genetic and biochemical resources for commercial purposes (for example, for therapeutic agents, cosmetics, biochemical catalysts and substances used in other commercial industries).

Bioregion (or ecoregion). Regions within Biogeographic Provinces with similar community structure (that is, species composition and relative abundance) and environmental conditions (for example, oceanographic, geologic and geochemical).

Chemoautrophy. Production of organic matter independently of photosynthesis and sunlight through the oxidation of reduced chemical compounds.

Chemosynthetic Ecosystem Reserves. Areas of the seabed managed to achieve the conservation goal of protecting natural diversity, ecosystem structure, function, and resilience of chemosynthetic ecosystems.

Chemosynthetic Ecosystem Reserve (CER) Networks. CER Networks within a bioregion or biogeographic province include multiple CERs with some level of connectivity (that is, exchange of organisms) among components of the network, managed together to achieve shared-use goals and objectives.

Chemosynthetic Ecosystem. An ecosystem that depends on microbial primary production based on chemautotrophic processes.

Community composition. The list of species (taxa) occurring within a community.

Community structure. The composition, relative abundance, trophic structure, diversity and size structure of species (or higher-level taxa) occurring in a community.

Connectivity - population. Linkage between species or populations through larval or other dispersive stages, resulting in the transfer of individuals and genetic material. By definition, connectivity plays an important role in sustaining metapopulations.

Connectivity - ecosystem. Linkage between ecosystems through transfer of organisms, materials and energy from one ecosystem to another. Ecosystem connectivity can play an important role in sustaining the structure, function and productivity of an ecosystem through transfers from donor to recipient ecosystems.

Ecosystem. Functional unit consisting of biotic and abiotic components linked together through factors including nutrient cycles, energy flow, species-habitatassociations.

Ecosystem-based management. A management approach that considers the whole ecosystem– including human dimensions–to achieve management goals.

Ecosystem structure and function. The components (biotic and abiotic), connections, processes and services that occur within an ecosystem. Key elements include trophic components and pathways, productivity and nutrient cycling.

Habitat heterogeneity. The variety, relative abundance and spatial configuration of habitat types (based on geological, geochemical, physical and biological parameters) found in an environment.

High Seas. A legal term from the United Nations Convention on the Law of the Sea to mean the water column of oceans, seas, and waters beyond national jurisdiction. As a legal term, the High Seas do not include the seabed and its resources. See also "Areas Beyond National Jurisdiction" and the "Area".

Management Unit. A broad-scale marine area that takes into account fundamental natural and human boundaries for the purpose of coordinated resource use and habitat protection.

Marine/Maritime Spatial Planning (MSP). A spatially-based management approach that engages multiple users to make informed and coordinated decisions about human uses of marine ecosystems and the conservation of marine biodiversity and ecosystem structure and function.

Marine Protected Area (MPA). Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.

Metapopulation. A group of spatially separated populations of the same species that interact through exchange of individuals (for example, via migration and larval recruitment). Although no single population may guarantee the long-term survival of a given species, the combined effect of many populations may accomplish this.

Mitigation. Methods for moderating or compensating for the force or intensity of an impact to a species assemblage or ecosystem.

Natural Conservation Unit. For individual species, Natural Conservation Units are defined by genetic markers as areas that share similar genetic diversity within a species. Natural Conservation Units may or may not be shared across species, and are often determined by scales of dispersal and connectivity.

Precautionary Principle. Principle 15 of the Rio Declaration states that: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Resilience. The capacity of an ecosystem to recover (that is, return quickly to its original state) from a perturbation without transition to a qualitatively different state controlled by a different set of processes.

Restoration. The act, process or result of returning a degraded ecosystem to a condition that resembles as closely as possible the pre-disturbance state. Alternatively, recovery of selected pre-disturbance attributes may be a restoration goal.

Seafloor Massive Sulphide (SMS). Deposits that may be rich in copper, gold, zinc and other metals, generally created as a result of past or present hydrothermal vent activity.

Seep. A seafloor ecosystem fueled primarily by chemoautotrophic production based on hydrocarbons generated by microbial and/or thermogenic degradation of organic material. Reducing chemicals providing energy include biogenic or thermogenic methane and sulphide. Seeps are often sediment hosted and/or involve the precipitation of authigenic carbonate. Active seeps typically support intense microbial production by archaea and bacteria that in turn support structure-forming, symbiont-bearing tubeworms, mussels, clams, sponges and snails. Inactive seeps consist of exposed or buried carbonates, often with fossilized seep organisms. Both active and inactive systems support some taxa from the background community.

Hydrothermal Vent. An ecosystem associated with submarine volcanic systems and the subsurface reaction of seawater and rock at high temperatures that delivers reduced chemicals to the seafloor. These chemicals fuel microbial chemoautotrophic production and methanotrophy that in turn support specialized metazoan communities distinct from the background community. Vents comprise the full cycle of hydrothermal activity, from inception of venting and microbial primary productivity through successional stages that ultimately culminate in cessation of fluid flow and relict or fossil deposits.

Annex II: Connectivity and dispersal at vents on mid-ocean ridges

Andreas M. Thurnherr

In order to evaluate connectivity, an important unknown in vent and seep ecosystems, information about dispersal is required. While time series of ocean velocities can be obtained (for example, with current meters and ADCPs deployed on moorings), the effort required, particularly in the deep sea, is costly and the resulting data are often inadequate for drawing meaningful conclusions about dispersal. This brief appendix discusses some of the underlying issues and aims to provide guidance on how to make appropriate measurements.

Dispersal in the ocean is strongly dependent on the relevant temporal and spatial scales. On time scales of weeks to months, which are important in the context of larval dispersal, advection (larval transport) by large-scale flows does not typically dominate dispersion (Speer, K. G. et al., 2003). Temporal and spatial variability in the oceanic velocity field cause any tracer cloud to spread in space. As a result the net dispersion in the ocean can be in directions other than the direction of the mean flows, including up stream. This implies that dispersal distances estimated from temporally averaged velocities measured at single locations (for example, progressive vector diagrams) are generally incorrect because they ignore any spatial variability in the velocity field.

To gain an understanding of the relative effects of advection and eddy diffusion on dispersion, information about the spatial variability of the flow field is required. This is particularly important near topography, where the flow speeds and directions often show significant variability over spatial scales in the order of 1km. There are two fundamentally different approaches to quantifying eddy diffusive dispersion: 1) Lagrangian (that is, flow-following) methods, such as float- and tracer-release experiments, are ideally suited to the purpose. Lagrangian measurements yield direct snapshots of dispersion, accounting for both advection and eddy diffusion; 2) Where collection of Lagrangian data is not feasible, some information can be obtained from simultaneous Eulerian (that is, fixed in space) measurements with sufficient spatial resolution to sample the dominant features of the regional flow field. It is important to note that suitable mooring placement requires prior determination of the regional circulation patterns. This can often be accomplished with hydrographic/velocity surveys with sufficient sampling to account for high-frequency variability, which is usually dominated by the tides and near-inertial oscillations. It may also be possible to determine the regional circulation patterns using numerical circulation models of sufficient spatial resolution (horizontal resolution of 1km or better is typically required).

To illustrate these points, consider dispersal near the Lucky Strike hydrothermal vent field, near the base of a topographic peak in the rift valley of the Mid-Atlantic Ridge near 37°N. Year-long current meter records obtained near the vent field in 1994/95 and in 2001/02 both reveal southward mean flow. The apparently reasonable inference that the hydrothermal material (including larvae) from Lucky Strike is dispersed predominantly southward along the rift valley is entirely wrong, however, because the mean flow averaged across the entire width of the rift valley is consistently to the north, as was determined by detailed oceanographic surveys carried out in 2006 and 2010, as well as from year-long current-metre measurements collected at more representative locations between 2006 and 2007. The southward mean flow observed on the earlier moorings is, in fact, part of a <5km-wide cyclonic circulation around the topographic high next to the vents (for additional details, see Thurnherr et al., 2008).

Even in much simpler topographical settings, dispersal can often not be evaluated without a good understanding of the regional flow patterns. Consider, for example, dispersal above the crest of the East Pacific Rise between 9 and 10°N. Hydrothermal-plume observations suggest mean westward flow across the ridge in that region (Baker et al., 1994; Lupton, 1998) but numerous current-meter records obtained near vent fields on the ridge crest indicate a highly variable velocity field with stronger meridional than zonal flows (for example, Marsh et al., *Nature* 2001). A comprehensive field experiment and extensive numerical experiments were required to understand that dispersion on time scales of weeks to months from sites on the ridge crest in this region depends strongly on the cross-ridge flow direction during the first few hours after the dispersant enters the water column (for additional details, see Jackson et al., 2010; McGillicuddy et al., 2010; Lavelle et al., 2010; Thurnherr et al., 2011).

While the characteristics of dispersion in these two example regions are fundamentally different it is important to note that: a) at neither site is it possible to draw meaningful inferences about dispersal from data collected on single moorings; and b) suitable locations for current-meter placement could only be determined after carrying out comprehensive regional CTD/LADCP surveys and, in one case, numerical experiments. While this may seem onerous, once the regional circulation patterns have been determined far fewer measurements are required to monitor the circulation. At Lucky Strike, for example, it is now possible to determine the direction and approximate magnitude of the along-rift-valley flow from only two CTD stations. This has allowed the circulation to be monitored every year since 2006 without requiring dedicated cruises.

Annex III:
Establishment of the Azores hydrothermal vent marine protected areas

The MAR hydrothermal vents: Lucky Strike, Menez Gwen & Rainbow	
Protected elements	• Physical structures of the vents • Natural integrity of the ecosystem, including its geological features, and genetic integrity
Management objectives	• Preserve the habitats, ecosystems and species in a favorable state • Maintain the ecological processes • Preserve the structural characteristics of the landscape and their geological elements • Preserve examples of natural environment for scientific studies, monitoring and environmental education • Preserve the natural reference conditions for the ongoing scientific studies
Development process	2000 • InterRidge workshop: "management and conservation of hydrothermal vent ecosystems". o Lucky Strike is considered a potential marine protected area. Moreover, the bases for an observatory at the MoMAR region (Menez Gwen; Lucky Strike, Rainbow and Saldanha hydrothermal vent fields) were being considered by the InterRidge scientific community. • WWF launches the proposal of Lucky Strike as potential MPA for the OSPAR network 2002 • Regional government of the Azores workshop on feasibility of creating MPAs at Lucky Strike and Menez Gwen o Workshop goals: • Characterize threats to sites (any activity that would compromise sustainable use of the ecosystem, or diminish, or adversely affect, the use or value of the resource) • Develop a zonation plan of the area • Develop and enforce co-operation and co-ordination • Create a code of conduct • Design a full management plan. • Combine conservation of the sites with user activities (tourism, scientific research, etc) • WWF launches the proposal of Rainbow as potential international MPA for the OSPAR network 2002-2009 • Several stakeholder events and publication discussion in the Azores • Presented and discussed at several OSPAR MASH and ICG-MPA working groups, which involve not only representatives of member countries but also several other organizations as observers
Stakeholder involvement (including at Portuguese and European/OSPAR level meetings)	• Scientists • Other experts, including in law • Fishermen professional associations • Scientific organizations (InterRidge and Ridge 2000) • International bodies (IOC and ISA of UNESCO) and NGOs (international: WWF, Seas at Risk, etc; Portuguese: Azorica, Quercus, etc) • Other organizations: ICES, OSPAR, NEAFC, etc • Officials from central and regional government of Portugal from the Ministries of Science and Technology, Environment, Biodiversity and Energy, Fisheries and Tourism. • European community

Implementation	Based on best scientific knowledge and best advice from the stakeholders involved in the 2002 Horta workshop, with presentations and discussions within the Azorean community. 2003 • Regional Government of the Azores submitted Proformas for the designation of Lucky and Menez Gwen as potential MPAs as part of the OSPAR network of MPAs to the Portuguese Head of Delegation to OSPAR. 2004 • Regional Government of the Azores submitted proformas for the designation of Lucky and Menez Gwen as MPAs to the Government of Portugal and the head of the Portuguese delegation to OSPAR 2006 • Portugal submitted Rainbow (the seafloor and sub-seafloor components) as a candidate national MPA under the high seas for the OSPAR Network of MPAs at the OSPAR/MASH meeting in Gotenburg, Sweden. An international proposal was already under discussion in previous OSPAR Working Groups meetings (ICG-MPA and MASH), based on a WWF pre-proforma 2007 • Rainbow MPA agreed by OSPAR contracting parties at the BDC meeting and that same year approved at the OSPAR/COP meeting • Portugal submitted Lucky Strike and Menez as a candidate MPAs for the OSPAR Network of MPAs at the OSPAR/MASH meeting in Horta (Azores, Portugal). • Submission of Lucky Strike and Menez Gwen MPA proposals to the European Commission – DG Environment to be part of Natura 2000/ Macaronesia • Regional Government of the Azores published the Law Decree of the Regional Network of Protected Areas. This Decree includes reference to the Marine Park of the Azores, which encompasses all the pelagic and sea-bottom areas of the EEZ and also the sea bottom areas in the extended shelf of the Azores. A specific new Decree for the Azores Marine Park is expected in 2010 2008 • Lucky Strike and Menez Gwen MPAs agreed by OSPAR contracting parties at the BDC meeting and that same year approved at the OSPAR/COP meeting • Lucky Strike and Menez Gwen submitted by Portugal as part of the EU Nature 2000 network 2009 • Lucky Strike and Menez Gwen approved as part of the EU Nature 2000 network
Activities permitted	• Scientific activities, with some spatial constrains and regulations (zonation) • Tourism is allowed under licence • Commercial activities such as mineral exploitation and fishing are not allowed
Management agency	Regional Government of the Azores

Stakeholder engagement

PROCESS: Presentations followed by discussions on 18-20 June 2002. Participate in the following working groups: 1) MPAs - Scientific basis; 2) Objectives, criteria for zonation; 3) Elements for a voluntary code of conduct and other approaches and instruments

Stakeholder group	Objectives
Scientists	• Define the frame of interests across different disciplines. • Combine the use of the area with different scientific interests and studies in progress. • Ensure accurate interpretation of scientific data. • Discuss possible boundaries. • Propose a zonation plan for the MPAs. • Explore, propose and discuss management issues.
Other experts, including in law	• Sources/status of existing international, European, national and regional laws. • Adequacy/implications of the legal and institutional capacities for creating and managing the MPA and dealing with access to the MPA. • Explore, propose and discuss management issues.
Fishermen professional associations	• Ensure key group of stakeholders are informed and involved in the process. This group may have interests in fisheries. • Explore, propose and discuss management issues. • Discuss possible boundaries.
Scientific organizations (InterRidge & Ridge 2000)	• Ensure a key group of stakeholders are informed and involved in the process. • Ensure accurate interpretation of scientific data. • Explore, propose and discuss management issues. • Discuss possible boundaries.
International bodies (IOC, ISA and UNESCO) and NGOs (WWF)	• Ensure key groups of stakeholders are informed and involved in the process. • Explore, propose and discuss management issues.
Officials from central and regional government of Portugal: Science and Technology, Environment, Biodiversity and Energy, Fisheries, Tourism	• Ensure a key group of stakeholders are informed and involved in the process and that the process will be followed up administratively. • Explore, propose and discuss management issues.
EC officials	• Not present in the 2002 meeting, but contributed to the discussion of the management plans, particularly during OSPAR meetings between 2003-2008, where these issues were widely discussed.
Other organizations	• From 2003 to 2008, many other stakeholders contributed to the discussion of the management plans in association with the OSPAR meetings where the plans and proposals were discussed.

Activity	Status in MPA						
	Menez Gwen			Lucky Strike			Rainbow
	Cat I	Cat IV	Cat VI	Cat I	Cat IV	Cat VI	Cat IV
Navigation							
Shipping	YES			YES			High seas Not protected
Recreation/tourism							
Touristic dive	Presumption against	Under licence		Presumption against	Under licence		Presumption against (Water column is high seas)
Structures							
Cables	No	Under License		No	Under License		Yes
Pipelines	No	No		No	No		No
Deployment of retrievable cages	No	Yes		No	Yes		Yes
Waste disposal							
	No			No			No
Mineral extraction	SCIENTIFIC ONLY						
Oil & gas	No	Under licence		No	Under licence		Under licence
Surface deposits	No	Under licence		No	Under licence		Under licence
Aggregate	No	Under licence		No	Under licence		Under licence
Energy (geothermic)	No	Under licence		No	Under licence		Under licence
Sound and seismic							
	Under licence			Under licence			Under licence
Fisheries							
pole and line	Under licence			Under licence			High seas
Surface long-line	Under licence			Under licence			High seas
Mid-water trawling	Under licence			Under licence			High seas
Bottom longlines	NO			NO			NO
Bottom trawling	NO			NO			NO
Deep-water gill nets	NO			NO			NO

Trammel nets	NO			NO			NO
Traps	NO			NO			NO
Research							
Observational and measurement (non-invasive)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Activity				**Status in MPA**			
	Menez Gwen			Lucky Strike			Rainbow
	Cat I	Cat IV	Cat VI	Cat I	Cat IV	Cat VI	Cat IV
Fluid sampling (non-invasive)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Experimental (instrumentation)	No	Yes	Yes	No	Yes	Yes	Yes
Biological and Geological Sampling (extraction)	No	Yes	Yes	No	Yes	Yes	Yes
Sediment sampling (extraction)	Presumption against	Yes	Yes	Presumption against	Yes	Yes	Yes
Transfers of animals, geological formations, sediments and fluids	No	No	No	No	No	No	No

Annex IV: Knowledge status

1. Location of ecosystems and potential activity sectors

Locations of approximately 200 known active vent sites and an additional eight inactive vent sites are now known to various degrees (from presence of diagnostic chemical anomalies in the water column to well-characterized sites like TAG or Logatchev) and are listed on an InterRIDGE-sponsored web database[1]. The International Seabed Authority also maintains a database of vent locations. Of the 200 or so known active vent areas, an estimated 50 per cent have had some level of preliminary sampling of some combination of rock, water and biota. The number of active hydrothermal sites per 100 kilometers of ridge axis varies from fewer than 0.5 to more than 4.5 (Baker and German, 2004).

- There are large regions of the global mid-ocean ridge for which exploration has barely begun, especially along the Pacific Antarctic Ridge, the Indian Ocean Ridges and the Arctic Ridges. There has been virtually no exploration on the Andaman Ridge, and there are a number of volcanic arc systems within which hydrothermal systems have not yet been fully located.

There is sufficient information about the distribution of vent fields to begin to address management goals, especially in certain regions such as the northern East Pacific Rise and Lau and Manus Basins.

- More information about the distribution of venting in other areas (for example, the northern Mid-Atlantic Ridge, southern hemisphere and Arctic ridge axes) would improve our ability to address management goals.

Our understanding of the distribution of different habitat types (black smokers, diffuse venting, ultramafic-hosted vents) and how habitat heterogeneity relates to biodiversity is developing and sufficient to inform preliminary management planning.

Scientists consider that fewer than 1 per cent of seeps on continental margins around the globe have been located, and even fewer have undergone preliminary mapping and characterization of biology and geochemistry. That seeps may be common and abundant features is exemplified by the recent discovery of more than 2,500 seeps in an area over 1,500 km^2 in the Dnepr Paleo-Delta of the anoxic waters of the western Black Sea at depths from 70 to 825 m (Naudts et al., 2010).

Although the central portion of the northern Gulf of Mexico is considered the most complex slope system in the world due to salt migration, it is also one of the best understood through the accumulation of 3-dimensional seismic survey data collected by the oil and gas industry. This data is also archived with the United States Federal Government. Greater than 99 per cent of the Gulf of Mexico seabed is comprised of soft sediments, but more than 9,000 features created by hydrocarbon seepage and chemosynthetic precipitation of authigenic carbonate have been identified. The responsible regulatory agency for protecting the environment from oil and gas activities (BOEMRE) considers all of these features as having the potential for the presence of significant seep communities. A list of sites confirmed by observation or sampling, now numbering approximately 100, is maintained by the agency.

While we have an incomplete understanding of all geological processes that provide seabed settings for seep ecosystems, geological exploration tools,for example, sub-bottom profiling, for example, Judd and Hovland 2007; Naudts et al., 2006, single-beam echo-sounding (bubble detection), for example, Naudts et al., 2010, 3-D seismic surveys used for oil and gas exploration (primarily in the Gulf of Mexico), and ROV mapping and visual observation, for example, Dupré et al., 2007; Greinert et al., 2010, can be effectively used to locate seeps. Thus, while we do not know details of the spacing of seep locations along all continental margins, they is theoretically knowable. Given the availability exploration resources, full global documentation of the presence and composition of seep biological communities is very unlikely to occur for many decades.

We have a very incomplete understanding of the distribution of seep taxa and seep biogeography. Seep biogeography appears to be correlated with water-mass distribution. Where water masses change depth with latitude (for example, along the Chile margin) there may be a much greater change in seep communities along a depth contour than with depth. In the Gulf of Mexico (a single water mass), seep communities are similar across 1,000 km or more along a given depth range, but there is nearly complete replacement of species from shallow (< 600 m) to deep (> 2,000 m) sites in the same region (Cordes et al., 2007). There are many data-poor regions covering most of the globe's continental margins where virtually nothing is known about the distribution and composition of marginal seeps (for example, the continental margins of South American, Eastern African, Indian Ocean, Antarctica and the Arctic).

2. Community composition (including endemism, diversity and other metrics) and genetic diversity within and between fields

We know a lot about community structure in certain habitats (especially mussel beds, tubeworm and provannid snail habitats) on the East Pacific Rise, portions of the Mid-Atlantic Ridge, Juan de Fuca Ridge, at a number of back-arc basins in the western Pacific, and at certain seep sites (for example, Gulf of Mexico, off Japan, in the Mediterranean, the Gulf of Cadiz), and this knowledge can be used to inform initial management plans. Our understanding of natural conservation units based on spatial scales of genetic differentiation is developing rapidly for certain key taxa (generally the numerical and biomass dominants), but there remain many more key species and life-history types to study.

- The extent to which distinctive biogenic habitats (such as tubeworms, clam beds and mussel beds) contribute to the overall species diversity in an ecosystem is not well understood for most vent and seep ecosystems.
- Our understanding of community composition and genetic diversity in many chemosynthetic habitats is relatively poor and we are ignorant as to how much genetic diversity is critical to sustain populations in spatially and temporally heterogeneous environments.

- We know virtually nothing about spatial scales of genetic structure in most taxa, nor about effective population sizes (Ne); taxa with small Ne will be at greater risk of local or global extinction.
- We have scarce or no knowledge of community composition, structure and function at inactive chemosynthetic sites.

3. Temporal dynamics and variability

Temporal variability in physicochemical parameters and ecological processes is key to predicting the resilience of a system to natural and anthropogenic disturbance. Long-term observations at some locations (for example, 9°N on the East Pacific Rise [21 yrs], Endeavour Vents [24 yrs], Lucky Strike [14 yrs], TAG [23 yrs], Lau Basin [5 yrs], Manus Basin [5 yrs]) document a range of site-dependent temporal variations and successional dynamics in different geological settings, as do chronoseres, where communities of areas corresponding to different lengths of time since the onset of colonization, and time-series studies at seeps in the Gulf of Mexico.

- Our understanding of the interplay between temporal variability, population dynamics and connectivity (for example, potential and realized dispersal and recruitment, frequency of dispersal and recruitment events) is very incomplete. It is important to understand natural variability in a system in order to interpret the relative scale of impact of anthropogenic activity.
- We would like to know more about variability of fluid flux and chemistry in different geological settings and to understand other aspects of geological dynamics. Natural variability of biogeochemical interactions is critical to interpreting the environmental impacts of human activities.
- Temporal dynamics in inactive systems is not understood at present, but communities are predicted to be more stable, with much slower dynamics (less resilience) than active settings.
- We need to improve our understanding of the intensity of impacts and temporal and the spatial scales of human activities likely to take place in chemosynthetic settings. For emergent activities such as mining, knowledge of the difference between modeled and actual activity and impact will be important for the implementation of adaptive management strategies to prevent loss of ecosystem function, maximize resource use, and improve future models.

4. Degree of endemicity and linkages between chemosynthetic and non-chemosynthetic (background) systems.

A large percentage of taxa found in active chemosynthetic systems are assumed to be endemic, but if they occur in non-chemosynthetic environments, even in low numbers, they may serve as a source of propagules. Export of chemosynthetic carbon into the surrounding, food-poor deep-sea expands the sphere of influence of chemosynthetic fields beyond the visible range of dense biomass.

- We currently lack a full understanding of the extent to which nominal vent and seep species are found outside the sphere of influence of vent and seeps. This knowledge is expected to be especially important for designing management strategies for inactive systems.
- We have limited knowledge of the sphere of influence of chemosynthetic ecosystems on the background ecosystem.

5. Ecological value.

How much of an ecosystem must be protected for it to persist and function?

- There is a need to assess the level of redundancy in an ecosystem, in order to set thresholds for the number of species and habitats a Protected Area should protect. While we know relatively little about this in regard to chemosynthetic ecosystems, we may use theory developed in other systems to inform best practices.

6. Commercial, scientific, cultural and educational 'value' of chemosynthetic ecosystems and their resources

The commercial values of extractive resources, for example, are relatively easy to establish based on commodity markets, but other values of chemosynthetic ecosystems can and need to be assessed.

- We need to improve our understanding of the multiple valuations of chemosynthetic ecosystems and resources.

7. Existence value of vents and seeps

Existence values of chemosynthetic ecosystems reflecting the benefit people receive from knowing that a particular environment exists can be generated through contingent valuation (market) surveys that assess willingness to pay to preserve.

- There is a need for a cross-cultural assessment of the existence value of vent and seep ecosystems, including comparisons of motives across geographic and socioeconomic variables.

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[1] *http://maps.google.com/?q=http://www.interridge.org/files/interridge/vents_interridge_2009_all.kml*

Annex V: Meeting overview and workshop participants

Chairs

Cindy Lee Van Dover, Duke University, USA
Craig Smith, University of Hawaii, USA

Participants

Jeff Ardron, Marine Conservation Biology Institute, USA
Sophie Arnaud, Ifremer, France*
Yannick Beaudoin, UNEP-GRID/Arendal, Norway*
Juan Bezaury, The Nature Conservancy, Mexico
David Billett, National Oceanography Centre, UK
Mark Carr, University of California, Santa Cruz, USA
Georgy Cherkashov, VNIIOkeangeologia, Russia
Adam Cook, International Seabed Authority, Jamaica*
Fabio DeLeo, University of Hawaii, USA
Daniel Dunn, Duke University, USA
Chuck Fisher, Penn State University, USA*
Laurent Godet, CNRS, CRESCO, France*§
Lisa Levin, Scripps Institution of Oceanography, USA*
Michael Lodge, International Seabed Authority, Jamaica*
Lenaick Menot, Institute Oceanographique, France
Karen Miller, University of Tasmania, Australia*
Debbie Milton, National Oceanography Centre, UK
Lievan Naudts, University of Ghent, Belgium
Conn Nugent, The Kaplan Fund, USA
Linwood Pendleton, Duke University, USA
Sophie Plouviez, Roscoff Marine Laboratory, France
Ashley Rowden, NIWA, New Zealand
Ricardo Santos, University of the Azores, Portugal*
Tim Shank, Woods Hole Oceanographic Institute, USA
Samantha Smith, Nautilus Minerals, Australia*
Chunhui Tao, COMRA, China
Akuila Tawake, SOPAC, Fiji
Andreas Thurnherr, LDEO, USA
Tina Treude, Geomar, Germany

** = Member, Organizing Committee*
§ = Local Host

Bottom Row (L-R): Plouviez, Dunn, Tawake, Cherkashov, Arnaud, Treude, Santos, Van Dover
2nd Row (L-R): Milton, Bezaury, Miller, Beaudoin, Lodge, Fisher, Cook, C Smith
3rd Row (L-R): Nugent, Naudts, Billett, Thurnherr, S Smith, Shank, Ardron, Rowden, De Leo
Top Row (L-R): Tao, Carr, Godet, Levin, Pendleton, Menot

Meeting overview

The first two days set the stage for the discussions and writing that are to take place on days 3 and 4.

Day 1. Morning:

Review basics, principles of MPA design and explore four case studies.

Day 1. Afternoon and Day 2, Morning:

Speakers summarize

- The physical, geological, ecological and biogeographic characteristics of vents and seeps (i.e. the distribution, dynamics and connectivity of vent-seep communities);
- Non-market and market values of vents and seeps, and perceived ecosystem threats, and
- The policies and politics of deep-sea conservation.

Day 2. Afternoon

Participants go into the field to continue discussion in informal settings.

Day 3

Develop management goals and priorities for vents and seeps. Then develop design principles that would allow these management goals to be achieved at vents, and give a hypothetical example for each type of ecosystem.

Day 4

Introduces outreach efforts and transitions to focused team efforts to further develop design principles that would allow management goals to be achieved at seeps. The Workshop closes with a key discussion and writing effort on policy recommendations.

- Speakers and panelists provide authoritative background and define the scope of the themes to be developed by workshop participants.
- Teams are used to create environments suited for accomplishing discussion and writing goals and to allow each participant to have a clear voice.
- Team Leaders report back to the Plenary and meet as a group to discuss and clarify prose at the close of each day.
- Workshop participants are asked to keep an eye on the Workshop Goals and outlined needs of the Science manuscript.

Project Teams

To increase the opportunities for all participants to contribute to discussions, we have assigned participants to teams, with representation across the natural science and social science disciplines. These teams break out for smaller group reflection and discussions, with reporting responsibility by Team Leaders in plenary session. Team leaders are members of the Organizing Committee and will be tasked with after-hours review and summation in collaboration with the Co-chairs. Each team also needs a scribe to record notes (names in blue have been nominated).

TEAMS for Tuesday and Wednesday

(The Co-chairs are not assigned to any group and will 'float'.)

*: Org. Ctte Member; Bold = team leader, Blue = recorders

TEAM A	TEAM B	TEAM C	TEAM D	TEAM E
Billett*	**Miller***	**S Smith***	**Santos***	**Lodge***
Menot	Cook*	Plouviez	DeLeo	Milton
Arnaud*	Shank	Nugent	Godet*	Fisher*
Levin	Beaudoin	Carr	Treude	Tawake
Cherkashov	Tao	Thurnherr	Ardron	Bezaury
Pendleton	Rowden	Dunn	Naudts	

TEAMS for Thursday and Friday

VENTS	SEEPS
Rowden	Levin
Arnaud	Ardron
Beaudoin	Bezaury
Cherkashov	Billett
Godet	Shank
Lodge	Cook
Milton	DeLeo
Nugent	Dunn
Pendleton	Fisher
Plouviez	Carr
Santos	Menot
S Smith	Miller
Tao	Naudts
Tawake	C Smith
Van Dover	Thurnherr
	Treude

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